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Popular Science

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MARCH 1993
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Recently, an independent research firm



compared the new
\$13,000* Nissan Altima*

against the \$26,550**
Lexus ES 300 to determine which car's body panels were put together with a higher level of precision.

The results were quite astonishing.

Thanks in part to Nissan's state-of-the-art robotic body assembly system and over 3500 precision welds, the Altima's tolerances between body panels proved to be every bit

as accurate as its stratospherically priced competition. In fact, the Altima is built with such precision that it had an average gap difference of just .018 inches***

What does this

mean in layman's terms?

It means the doors fit snugly, the trunk shuts soundly and the hood closes perfectly. It also means the automobile offers such structural soundness that

Nissan Motor Corporation U.S.A. Smart people always read the fine print. And they always wear their seat belts. *Manufacturer's suggested retail price for 1993 Nissan Altima XE excluding taxes, title, license, destination charges and options. **Manufacturer's suggested retail price for 1992 Lexus ES 300 excluding taxes, title, license, destination

If you were impressed
when you saw Lexus do this test,
wait until you read this.



And noise is so minimal
that at 55 mph, the
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assist the driver. All
four doors have been
triple-sealed to help
keep out moisture.

Slide inside the

have been specially



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Altima



*It's time to expect
more from a car.™*

charges and options. ***Based on independent tests conducted by USAC. Body panel tolerances based on average gap consis/
Nissan Altima XE or SE vs. 1992 competitive vehicles. Slalom comparison based on course completion time. Interior quiet

This One



8FWD-8GA-2GUH

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USA



MARCH 1993

Founded in 1872/Vol. 242, No. 3

COVER STORY

56

Secret Mach 6 spy plane

An eyewitness description, a secret Nevada test site, and a new look at advanced aerodynamics paint a portrait of Aurora, America's newest secret reconnaissance aircraft. A Federation of American Scientists report also posits the existence of the plane, along with others flying in the Pentagon's "black world."



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66 A house for all reasons

The architectural style may be classic Mediterranean villa, but the 1993 New American Home contains some of the most technologically advanced home-building products available today, complementing the home's energy-saving and environmentally friendly themes.



74 The unbearable lightness of space travel

Prolonged weightlessness in near-zero gravity could endanger human health, as well as NASA's plans for long missions. The ill effects include muscle-wasting and heart shrinkage. Here's how researchers are studying the problems—and hope to solve them.



80 Minivans to the max

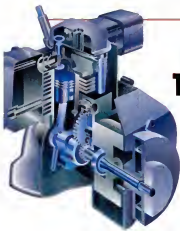
Volkswagen EuroVan, Mercury Villager, Nissan Quest, and Dodge Grand Caravan: One is the tallest, two are the widest, and one is the longest. We tell you which is which and which is the best.



90

The little engine that could

This one-cylinder four-cycle gas-powered engine is lightweight enough for hand-held outdoor power equipment—and clean enough for stringent emissions standards that are coming soon.



COVER ILLUSTRATION BY KERRY LESLIE

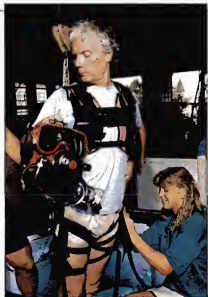
From The Editor

The existence of a high-flying black project, code-named Aurora, has been suspected for years. Indeed, this magazine was among the first, in November 1988, to describe such an aircraft. It now appears that the evidence is substantial beyond a doubt. In our cover story this month, author Bill Sweetman pieces together a vivid portrait and an operational scenario of America's latest secret spy plane.

U.S. officials from the Congress to the Pentagon firmly deny Aurora's existence. But then, that's their policy. Sweetman, however, is among the most knowledgeable aviation journalists in the world. And his conclusion—that we've spent billions of tax dollars to build and fly aircraft the public has not been told about—is supported by the prestigious Federation of American Scientists.

Ear- and eyewitness reports, expert analysis of aviation technology that is known to exist, and even the government's own seismic records all fit into Sweetman's detailed account of the latest thing in the air that supposedly doesn't exist. See if you don't agree.

Robert Gannon is a long-time contributor to this magazine who has an undeniable penchant for getting close to his work. From his underground account of the Chunnel digging between France and Britain to his up-to-the-treetop reporting on scientific studies in the Costa Rican rain forest, Gannon is a man who is hard to separate from the subjects of his stories.



Contributor Robert Gannon suits up for a microgravity experience.

In this issue, he weighs in with a first-hand account of research on the physiological effects of weightlessness.

Gannon walked a treadmill underwater and jogged in place—vertically—to experience the Mars-like microgravity astronauts will encounter during future space missions. Somehow, amid all this grueling physical activity, he also managed to put together an update on the progress that scientists are making in understanding and contending with the effects of near-weightlessness.

Not quite weightless, but close, is Ryobi's tiny four-stroke engine. This little wonder is apparently the breakthrough needed as the deadline for stringent emissions regulations for outdoor power tools rapidly approaches, first in California in 1994, and eventually everywhere else. Associate Editor Judith Anne Gunther (formerly Judith Anne Yeaple) provides a closeup look at Ryobi's accomplishment other manufacturers will surely try to follow.

Contributing editor Michael Morris returns with a report on the New American Home, a smorgasbord of high-tech construction products, techniques, home fixtures, and electronic furnishings. This, too, is a case of hands-on reporting. In our partnership with the National Association of Home Builders, Morris served as the new-technology guru for this model house. The structure reflects progressive design and engineering in the areas of environmental friendliness, electronic home management, entertainment and education, and handicapped accessibility. No doubt you'll see why we call it a house for all reasons.

Frederick A. H. [Signature]

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November 1988: POPULAR
SCIENCE reports on Aurora.



"I recommend SwingMate to anyone looking to improve their swing."



Ken Venturi

*Pro instructor and former
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Readers Talk Back

Blackbird blooper?

The editorial-staff picture in front of the SR-71 Blackbird that you labeled the A-12 deserves a big "duh!" ["From the Editor," Dec. '92]. I'm laminating, framing, and hanging this beautiful blooper.

Michael R. Elfindale
Hilo, Hawaii

My lovely new bride, Michelle, pointed out that the picture is of the famous SR-71 Blackbird. In the future, please call Michelle when it comes to aircraft.

George Major, Cambridge, Mass.



A side view of the A-12 Blackbird, the plane that appeared on page 4 of our December 1992 issue.

Many people don't know it, but there were at least two earlier versions of the SR-71; the one pictured in the December issue is the A-12. It is a single-seat predecessor to the two-seat SR-71 Blackbird, which looks, and is, very similar to it (see photo on page 62). The A-12 was built for the CIA and flown by CIA pilots. The government then decided to proceed with the SR-71 variant, which was operated and piloted by the Air Force. Both are Lockheed Skunk Works products designed by the legendary aeronautical engineer Kelly Johnson.—Stuart F. Brown

Material matters

What do you mean when you say that SEAgel is lighter than air ["Science Newsfront," Oct. '92]? A lead balloon would also float away if not for the air inside.

Ed Cobb, Columbia, Md.

I found the "Lighter than Air" article

confusing. If two things are mixed together, in whatever ratio, and one is air and the other is lighter than air, the resultant is bound to be lighter than air.

Henry Ariail, Sewanee, Tenn.

The SEAgel material is riddled with microscopic pores; any gas the material is exposed to will fill the pores. If you were an air molecule, SEAgel would look like "a ten-foot wall with a nine-foot door in it," explains Robert L. Morrison, the scientist who invented the material. While the "walls" themselves are not lighter than air, a chunk of SEAgel without any air in it is lighter than an equivalent volume of air. Unlike a lighter-than-air balloon, SEAgel is a solid—it doesn't have a hollow center.

—Dawn Stover

Apples and oranges

It's wrong to compare the destruction of the Brazilian rain forest with the logging of the Oregon forest ["Science Newsfront," Nov. '92]. The Brazilian rain forest has been replaced by agriculture, while the Oregon forest has been replanted and is still a forest. I live on land that has been logged several times, and I assure you there are not fewer species of wildlife, but more! It also supports 24- to 30-inch-diameter 60- to 80-foot-tall trees that some would call "old growth."

P. M. deLaubenfels, Corvallis, Ore.

As our story noted, Oregon's national forests are replanted after logging, while Brazilian forests are typically converted to agricultural uses. There is ample evidence, however, that forests may take centuries to recover from clear-cutting. For example, a recent study of Appalachian hardwood forests that were clear-cut as long as 87 years ago reported that the forests contained only half as many plant species as similar forests that were never logged.—Dawn Stover

Editor's note: Sewer Shark ["Games CD-ROMs Play," Dec. '92] was developed by Digital Pictures and is published by Sony Imagesoft.

Address letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Or fax your letter to us at 212-481-8062. Letters may be edited for space and clarity. We regret that we cannot answer unpublished letters.

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In Search of Balance

Ninety-two percent of all Americans believe that a balance can be struck between environmental protection and economic development. Our 1992 national public opinion survey with The Roper Organization showed that almost every American wants greater efforts made to protect the environment and believes that insufficient progress has been made to date. We must find balanced solutions to environmental problems that can be supported by the four out of five Americans who are concerned about the environment.

Judging from the rhetoric in most of the environmental debate, however, balance is an elusive concept. Too often, environmental problems are portrayed as either/or choices where no middle ground exists between environmental protection and economic progress. It's the greens versus the browns.

Times Mirror Magazines Conservation Council

In 1990, this magazine joined with the 11 others in the Times Mirror Magazines family to form the Times Mirror Magazines Conservation Council. Its goal: to involve our 30 million readers in the conservation of natural resources.

Throughout 1993, we plan to continue supporting balanced solutions to natural resource problems. Balancing requires a focus on long-term economic and environmental solutions, rather than letting outcomes be dictated by short-term economic or environmental dislocations.

We support a conservation approach to natural resource solutions rather than preservation. By conservation we mean that natural resources can be both protected and used through careful management. Preservation means protecting natural resources by locking them away from human use. Our public opinion poll showed that seven out of ten Americans favor a conservation approach to natural resource management; only



one in four Americans is a preservationist.

Balanced environmental solutions also result from increased environmental education. Education creates awareness, and from awareness springs action. By helping Americans to realize the importance of a healthy ecosystem and its role

in supporting a sound economy, balanced actions to solve problems will be developed. To promote such

a realization, the Conservation Council has created the Partnership for Environmental Education, which provides grants to help local environmental education efforts. If you know of programs we should be supporting, we'd like to hear from you.

Some readers question why we devote our magazines' pages to features like the Voters' Guide to Environmental Issues for the fall 1992 elections. We believe that if we do not try to stem the tides of resource degradation and environmental overreaction, the results will be both lost opportunities to enjoy natural resources and a loss of precious biological diversity.

The Issues

Here's where our Conservation Council will be working with the Clinton administration and the new Congress:

- **Public Access to Public Lands.** The General Accounting Office has found that 50.4 million acres of public land lack public access, an area about the size of most of the East Coast states added together. The use of these lands is blocked when private landowners close access roads. This gives them exclusive use of land to which each American has an equal right.

The answer? Increased appropriations for the acquisition of easements to access public lands along with documentation of where legal access already exists. Our survey showed that a majority of Americans believes resolving blocked access to public land is an important priority. President Clinton agrees, having promised in our Voters' Guide that, if elected, "I would

Illustrations by Bob Mansfield

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Popular
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SKI
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OUTDOOR LIFE

Salt Water
SPORTSMAN

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work to ensure appropriate access to public lands."

- **Clean Water Act.** The Conservation Council has an active interest in the Act's reauthorization as it pertains to wetlands and water quality improvement. Water quality and wetlands protection are important concerns among our readers, even more than for the general public—79 percent of whom believe more effort is needed to fight water pollution. President Clinton supports a "no net loss" of wetlands policy and has promised "to work with the scientific experts at the National Academy of Sciences to devise appropriate policies to protect our wetlands."

- **Marine Fisheries.** The main law governing marine fisheries management is up for reauthorization in 1993, and this couldn't come soon enough. Marine fisheries are in their worst shape ever. Sixty-four out of 101 species for which information is available are overfished. Greater conservation is needed to bring back fish stocks and the resultant economic benefits of their use. The financial incentive to over-harvest fish must be removed in certain cases, such as the striped bass, by making these available only for sport. Eighty percent of Americans are prepared to limit commercial fishing to protect fish stocks—even if this means paying more for fish.

- **1872 Mining Law Reform.** The current law is antiquated and needs updating to 20th-century needs. However, the law has spawned an industry with its attendant mining communities. Changes in this law should not result in major local disruptions or threaten the supply of hard-rock minerals. Allowing miners to buy public land for five dollars or less an acre under the current law should cease. But other mechanisms to ensure that miners are able to capitalize on their risky investment in locating a viable claim should be put in place. Bonding to make

POPULAR SCIENCE'S ENVIRONMENTAL MISSION

Environmental issues have always played a prominent part in POPULAR SCIENCE's editorial menu. Clean air and water, biodiversity, and unspoiled natural resources are vitally important to our readers, as to the population at large. But by the very nature of their interests, our readers want to learn about the impact of science and technology on environmental quality.

To that end POPULAR SCIENCE has published—and will continue to publish—articles demonstrating our conviction that science and technology have an ever more powerful role in fostering environmental well-being. The critical issues we've covered include global warming; zero-emissions electric cars; the chemistry and meteorology of the ozone hole; cleaning up oil spills with bacteria; the dangers of "tight" houses; and using bioremediation to handle toxic and nuclear wastes. Nothing could better exemplify our commitment than our July 1992 special issue, "Environment and Technology," which explored this theme in every feature and department.

Future articles will include such topics as clean coal, non-fossil fuels, the status of cold fusion, and the promise of fuel cells.

sure mined sites are restored should always be required. And a royalty should be phased in, with the funds used to restore areas damaged by previous mining. Such a royalty is supported by 76 percent of Americans.

- **Endangered Species Act.** We support a strong endangered-species law, based on scientific judgment, that considers the costs of protection. Cost considerations, however, should not be used in deciding whether or not the species is endangered; that should be based solely on the ecology of the animal or plant. Our public opinion survey showed that most Americans want tough natural resource questions answered by scientists.

President Clinton agrees, having said, "I believe listing decisions for species under the Endangered Species Act should be based on science, not politics."

A Conservation Peace Corps

One of the most exciting ideas President Clinton mentioned in his response to our Voters' Guide questions last fall was his desire to create a civilian conservation corps "as a low-cost way to restore infrastructure on public lands." We support this idea and believe our readers can help make this happen. We would like to turn words into actions, under the banner of a "Conservation Peace Corps."

One approach to a conservation corps would be to recruit disadvantaged youth from the inner city and involve them in the restoration of natural resources and public infrastructure on public lands. This might involve the use of military resources that have become redundant with the end of the Cold War. Our Conservation Peace Corps could bring disadvantaged youth into the mainstream and improve natural resources and outdoor recreation across the country.

WHAT DO YOU THINK?

The Times Mirror Magazines Conservation Council was developed to reflect your views. We give our readers a voice in Washington, D.C., as part of their subscription. But we need your input to make sure we're on the right track. We will take your viewpoints into account.

- 1.) What do you believe are the three most important natural resource problems in America?
- 2.) Which conservation problems should Congress and the Clinton administration be addressing?

- 3.) Does our agenda for natural resources reflect your sense of balance between environmental protection and economic growth?
- 4.) Would you be willing to donate one weekend day a month to a Conservation Peace Corps for environmental restoration of public lands?
- 5.) Should the Clinton administration make the creation of a Conservation Peace Corps a priority?

Please send your responses to any of these questions to: Dr. David B. Rockland, TMM Conservation Council, 1705 DeSales St., N.W., Suite 801, Washington, D.C. 20036. Thank you.

WHAT'S NEW

EDITED BY JUDITH ANNE GUNTHER, SUZANNE KANTRA, AND MARCELLE M. SOVIERO



SLEEK SINK

The Vitraform sink features two layers of laminated glass that are shatter-resistant and more durable than porcelain. The \$650 sink comes in seven standard colors with either a clear or frosted finish, or may be custom-designed. Cherry Creek Enterprises, 3500 Blake St., Denver CO 80205.

COLORFUL CUBES

Lumino Optical Filter Prisms are smooth, faceted chunks of optical-grade acrylic manufactured in pure hues. The scratch- and fade-resistant blocks measure 1 by 1.5 by 2 inches. A six-piece Explorer Kit, a colorful addition to the executive desktop, costs less than \$50. Luminati Ltd., 6 Mount Vernon St., Suite 229, Winchester MA 01890.



POWER-STINGY PC

The Z-Lite 320L Model 60W features a power-conserving microprocessor, enabling it to run from three to six hours on its nickel metal-hydride battery. The 3.9-pound unit has a backlit 8.5-inch VGA display, two PCMCIA card slots, and a two-button pointing device. Price: \$2,200. Zenith Data Systems, 2150 E. Lake Cook Rd., Buffalo Grove IL 60089.



FEEL THE BEAT

For those who feel there's never enough bass coming from their car stereos, here's the A2-50 car-seat vibrator system from Tokyo-based Yupiteru Industries.

Connected to a car audio system, a special drive amplifier powers vibrating actuators that wedge between the backrest and the seat. You literally feel the bass through the seat of your pants. It sells in Japan for about \$380.



SEA SUIT

The SissitenAir Survival Suit features an insulated, layered skin with air pockets; when the pockets are inflated using either the integrated CO₂ gas canisters or built-in mouthpiece, the suit acts as a personal life raft. Price: \$2,000. Mariner Resource Corp., 86 Orchard Beach Blvd., Port Washington NY 11050.





DOUBLE TROUBLE

A U-lock and motion sensor on the Cycle Alert alarm cause double trouble for prospective thieves: If the motorcycle is moved for more than four seconds or if the cable is cut, a 107-decibel alarm sounds. Six versions are available for sports gear ranging from skis to snowboards. The Cycle Alert is approximately \$70. Sports Alert, 233 Wilshire Blvd., Suite 325, Santa Monica CA 90401.



PAPER TABLE

Although it's made of recycled paperboard, the 12-pound Qwork Bench supports up to 200 pounds of evenly distributed weight; the secret is the triangular shape of its components. The table stands 36 inches tall, though the legs can be trimmed along the printed stripes to lower the height. Price: \$30. NEWance Inc., 1765-H Carliland Ct., Addison IL 60101.



DESIGN IN 3D

PC users who have designed rooms with Autodesk's Home Series project-design software can now add three-dimensional quality to their plans. Simply load the former plans into the company's 3D Plan for a three-dimensional view—complete with room specs, color, and shading. Click on an icon and the view of the room changes from, say, looking through a window to looking through a door. Price: \$50.



BUBBLE WASH

Sharp claims its ES-BE65 automatic bubble-action washing machine uses 30 percent less water than conventional machines. Its cleaning process, a combination of rising air bubbles and horizontally swirling water, includes an optical sensor that determines the amount of dirt on clothing and then adjusts the amount of air bubbles accordingly. The machine is available only in Japan.



SLEEK TWO-SEATER

Gull-wing doors distinguish Mazda's AZ-1 two-seater minicar from other Japanese minicars. The AZ-1 has a midship, three-cylinder 660cc engine with a five-speed manual transmission and an all-plastic body. It's sold only in Japan.

WHAT'S NEW



THREE-WAY FRIDGE

Using gas-absorption technology, Igloo's Survivor cooler runs on alternating current, a car's cigarette lighter, or propane gas. The 36-quart cooler is equipped with a thermostat and an ice-tray shelf. Propane safety features include a gas pilot igniter and shut-off valve. Price: \$230. Igloo Products Corp., Box 19322, Houston TX 77224.



COMPUTERS ON TV

Laptop TV is a computer-to-video converter. It takes the video signals from your personal computer and changes them into professional-quality TV signals for business presentations or recording on your VCR. Its anti-flicker technology eliminates a jittery picture, a problem common to converted signals. The 2.5-pound converter costs \$1,195. Willow Peripherals, 190 Willow Ave., Bronx NY 10454.



ILLUMINATING WORK

Tucked into the spine of this business portfolio is a telescoping flexible lamp that lights the letter-size writing pad. Priced at about \$50, the Periscope Lighted Portfolio uses four AAA batteries and has compartments and a zippered pocket for documents, business cards, and pens. Pacemark, 100 W. 32 St., New York NY 10001.

SPLIT-HANDLED RAKE

With its two handles and tilted shaft, the curiously shaped AcceleroRake allows for easier, more efficient raking. The rake is used with a side-to-side sweeping motion, or the base can be rotated 90 degrees to rake material toward you. Price: less than \$20. Garden Weasel Division, Faultless Starch/Bon Ami Co., 1025 W. 8th St., Kansas City MO 64101.



LUXURY WAGON

Mitsubishi's Diamante luxury station wagon features a three-liter, 175-hp V6 engine with a four-speed automatic transmission. The high-rafter cabin offers more headroom for front- and rear-seat passengers, as well as 37 cubic feet of cargo space with the rear seat up. A driver-side air bag is standard, and antilock brakes are an option. Price: \$22,400.



Chevrolet Motor Division presents the definitive die-cast replica of America's sports car.



The hood opens to reveal the powerful 350 cubic inch engine.



Shown approximately actual size of 7 1/4" (18.42 cm) in length. Scale: 1:24.



The dash is highly detailed and shows full digital instrumentation.

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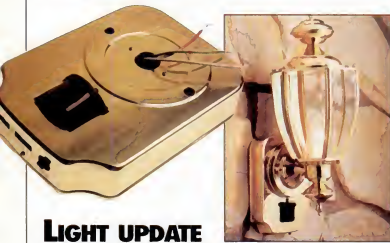
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Franklin Mint Precision Models

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WHAT'S NEW



LIGHT UPDATE

Inteletron's Motion Detector Mounting Plate converts your existing outdoor lighting fixture into a motion detector. Able to detect sources of heat up to 30 feet away, the unit can be adjusted to turn off the light after one, three, or five minutes. The S30 model BC90 is available in polished or antique brass, black, or white. Inteletron, 21021 Corsair Blvd., Hayward CA 94545.



NEW LOOK IN EUROPE

Barely two years after its 1990 launch, the European Ford Escort has been reengineered for 1993 with a striking nose and tailgate, larger rear-light assemblies, integral safety cage, and side-impact-protection door beams. Seven gas-engine options and a diesel version are available; a continuously variable transmission is another option on the 1.6- and 1.8-liter Zetor 16-valve injection units.



LOCK YOUR STOCK

Thumb Lock safety fasteners attach to the side of a computer or other high-tech gear to prevent jarring and restrain equipment that weighs between 50 and 200 pounds. The fasteners come in packages of two and cost between \$10 and \$16. Fastening Solutions, 15236 Burbank Blvd., Suite 101, Van Nuys CA 91411.

COST CALCULATOR

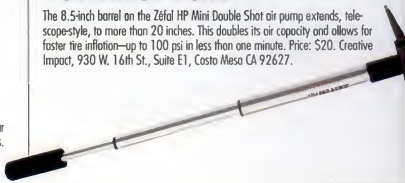
The Teletric measures the energy consumption of any electrical appliance and calculates its cost of operation. Rates from your electric utility can be input using the function keys. When Teletric is connected to appliances that run intermittently, the device adds up consumption over time.

Response Co. Ltd., PRI House, Moorside Rd., Winchester, Hampshire, SO23 7RX, England.



TINY, POWERFUL PUMP

The 8.5-inch barrel on the Zéfal HP Mini Double Shot air pump extends, telescope-style, to more than 20 inches. This doubles its air capacity and allows for faster fire inflation—up to 100 psi in less than one minute. Price: \$20. Creative Impact, 930 W. 16th St., Suite E1, Costa Mesa CA 92627.



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In the new Intrepid, you'll find airbags are standard for both the

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In fact, throughout Intrepid you'll find what *Motor Trend* calls "touches of genius." To us they're simply things that make good sense. And now that we've seen what's possible in a four-door sedan, we can't see building one any other way.



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the details."

-Automobile Magazine

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WHAT'S NEW

THE DETAILS, PLEASE

Using Black & Decker's Variable Speed Powerfile, with its long, narrow sanding belt, is easier than sanding corners, crevices, and other detail work by hand. The 1/2-inch-wide belt can be applied to wood, metal, plastics, and ceramics. Model 7463 is equipped with a variable-speed 2.8-ampere motor and a dust-collection system. Price: about \$80.



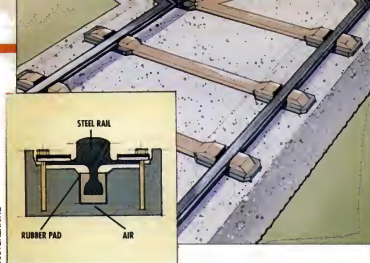
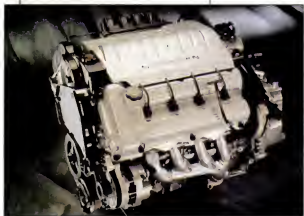
TABLETOP SUPPORT

Made from aircraft alloys, the Quadpod offers stable tabletop support for a camcorder when you're previewing or editing videos. The device locks the camcorder into place and adjusts with one knob. Price: \$75. Envision Products, 1430 Willamette, Suite 551, Eugene OR 97401.



V8 DERIVATIVE

The latest in General Motors' overhead-cam engines will debut in 1994 in the Oldsmobile Aurora personal luxury sedan. A derivative of the 4.6-liter Northstar V8, the Aurora four-liter V8 develops 250 hp at 5,600 rpm versus 295 hp at 6,000 rpm for the Northstar.



JANA BERENING

RUBBER RAILS

This shock-absorbing track system cushions steel rails on rubber pads, enabling trains to run faster while reducing noise and maintenance work for the operators—and without jarring passengers. The designers estimate that the rails, now undergoing testing in Sweden, would cost only 6 percent more than traditional systems. Cito Trading Co., Igelskattsvägen 12A, 4536 50 Hovås, Sweden.



PROTECTED PADLOCK

A tough plastic cover shields Master Lock's 1 1/2-inch steel padlock from dirt as well as rust-inducing rain and snow. The plastic also prevents the lock from marrying surfaces. Price: about \$10. Master Lock, 2600 N. 32 St., Box 10367, Milwaukee WI 53210-0367.

ON-SITE CHARGER

Instead of carrying numerous battery packs, contractors and carpenters can recharge cordless tools using a car or truck battery. DeWalt's automotive charger model DW9105 recharges 9.6-, 12-, and 13.2-volt battery packs in 90 minutes. The \$119 device will not overheat the battery pack during charging. DeWalt Industrial Tool Co., 626 Hanover Pike, Box 158, Homestead MD 21074.



THE GENUINE LEATHER U.S. ARMY FIELD JACKET

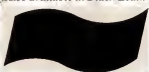
Millions of fighting men swear by it. Now, you can own it in genuine leather!

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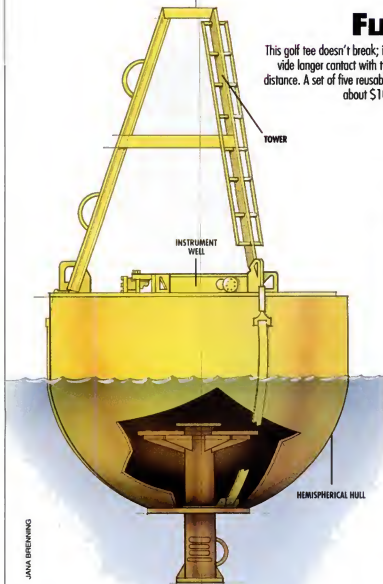
CLASSIC LOOKS

Ferrari shuns the flashy looks of its recent models for the new 456 GT, which backtracks two decades to revive the classic lines of yesteryear. No longer mid-engined, the coupe has an up-front 5.4-liter V12 that develops 442 hp. The car sprints to 62 mph in just 5.2 seconds and has a top speed of more than 185 mph. The price? Plan on about \$250,000.



FLEXIBLE TEE

This golf tee doesn't break; it bends as it's struck to provide longer contact with the ball for more control and distance. A set of five reusable plastic Power-T tees costs about \$10. Part-America, Box 3437, Wallington NJ 07057.



JANA BRENNING

HEAVY-DUTY BUOY

This buoy's sturdy, egg-shaped hull not only withstands battering waves and foul weather, but increases maximum buoyancy about 40 percent to 17,000 pounds, say its designers at the Woods Hole Oceanographic Institution in Massachusetts. The nine-foot-wide buoy will soon be deployed off Bermuda to help researchers study mooring materials and ways to recover data from underwater equipment.



SPACE-AGE CASE

Modular shelves in the Spacecab medicine cabinet reconfigure to accommodate bottles and containers of various sizes. Made from molded plastic, the cabinet weighs half as much as steel. Price: \$50 to \$250, depending on size and framing. Zoca Inc., 31111 Via Calinas, Westlake Village CA 91362.

DUSTLESS DRILLING

Hitachi's 7/8-inch hammer drill features an unusual dust-collecting device, making it especially useful for overhead work. A telescoping dust-collection tube retracts against the pressure of the workpiece as the bit drills; when it stops, the tube returns to the length of the bit. The model DH22VD variable-speed drill has both hammer and rotary modes. Price: \$511.





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— Hans Fintel, *The New York Times*



The Bose Lifestyle® music system: music center with CD player and AM/FM tuner (above), speakers (top left, also available in white), and hideaway Acoustimass® bass module (not shown).

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Edited by JOHN FREE

British TV goggles

You could be walking around wearing your own personal television goggles within a year—for about \$500. British inventor William Johnson's Goggle Vox puts a pair of 2.5-inch (diagonal) liquid-crystal displays (LCDs) in a black-out housing just inches before your eyes. At 10X, the tiny twin images produce a wide-screen effect that, when joined with stereo headphones, gives you the feeling that you're carrying your own personal viewing room wherever you go.

"What Walkman did with sound, Goggle Vox does with pictures," says Johnson, whose invention credits include Adidas's computerized Micro-pacer sneaker several years ago.

Goggle Vox accepts signals from VCRs, video discs, broadcast TV, and even computers for intriguing virtual-reality applications. The key technology is a transparent plastic coating over the miniature LCD screens that allows them to be magnified without sacrificing viewability.

Five years ago, Johnson, with a team of physicists, began searching for a better way to display video pictures. Other researchers had concentrated on increasing picture resolution by reducing the size and increasing the number of picture elements (pixels) displayed on-screen. But this all-electronics approach was expensive.

Focusing instead on the display surface, Johnson's team found its answer in a Du Pont-developed plastic monomer. Laminated sheets of the monomer, dubbed Microsharp, create a layer of microlenses. Pasted over the surface of the screen, the microlenses smooth the boundaries of 100-micron pixels and greatly boost the viewing quality of tiny TV screens. Others have patented a similar technique ("Wall-Size TV From Tiny LCDs," June '91).

At 10X, a 2.5-inch-diagonal LCD is a meaningless jumble of black-edged pixel boxes. Softened by Microsharp, however, the pixels blend together to create a picture not quite as good as a regular TV set, but vastly better than



Video goggles invented in Britain have plastic sheets with microscopic lenses covering two LCD panels. The lenses minimize the coarseness of an image (above right).

the straight magnified image or the tiny, unmagnified picture.

Johnson hopes to license the technology to major electronics firms. "This is an application that can be done very easily and immediately," he says.—Mark Henricks

...and Visortrons from Japan

Sony, which pioneered the stereo Walkman, is once again readying a new form of personal entertainment—this time with video instead of audio. Sony's new Visortron, worn like a set of oversize ski goggles, puts a liquid-crystal-display (LCD) panel in front of each eye. The LCDs are tiny but so close to the eyes that the viewer has the impression of watching a 33-inch TV from four feet away. "It's like watching a movie from the best seat in the theater," says Daiji Takahashi, the Sony manager who led the six-year-old project.

The Visortron can be connected to Sony portable 8mm video players and camcorders with a single proprietary plug, or to other video equipment with a three-pin adapter. Takahashi says advances in LCD fabrication techniques allow Sony to put 103,000 pixels on each 0.7-inch LCD panel. "We believe it is the highest resolution in the industry," he says. And with two screens, the Visortron can reproduce stereoscopic 3-D images. The company is investigating virtual-reality applications for Visortron as well.

But despite the eye-popping clarity

and image size, it's hard to forget you're wearing something that weighs about nine ounces. It's also a little disorienting to realize that you're unable to turn your eyes away from the screen.

In fact, worries about eyestrain from extended use led Sony to have two medical institutions test the device. "It was developed for consumer use but the medical issues need to be considered," Takahashi says. The company is particularly concerned about children using the Visortron to play video games for hours. Though



Sony's Visortron video goggles give the viewer the impression of watching a large-screen TV from four feet away.

the labs concluded there wasn't any evidence of harmful effects on the eyes, Sony is playing it safe, introducing the Visortron in controlled settings. Japan Airlines will use it for in-flight entertainment this year.

But there's yet another barrier to a consumer version: The two high-resolution LCD panels make the Visortron rather expensive.—Dennis Normile

Interactive-TV redux

There have been quite a few attempts recently to transform the home television into an interactive medium—none of which has really caught on. Now a new effort that promises superior performance hopes to turn interactive TV into a home-entertainment staple.

The 3DO Interactive Multiplayer, developed by Dave Morse, Dave Needle, and R.J. Mical—the team that

created the Amiga computer and the Atari Lynx video game—could be on the market by December. Applications include high-speed action and adventure games, educational software, and interactive movies; one such film will be based on Steven Spielberg's techno-thriller *Jurassic Park*. In fact, extra footage of the movie is being shot for the 3DO format.

Peter Black, president of Xiphias, a software publisher in Los Angeles, believes the new machine "could be a direct competitor" to hot game systems such as Nintendo and Sega, and could rival VCRs if the machine delivers what it promises—especially the ability to play back full-motion video.

According to Trip Hawkins, founder of the 3DO company, the machine will play back pictures with double the resolution of a VHS video tape and display 16 million colors with 50 times greater animation than current compact-disc interactive machines. The hardware will feature a built-in CD-ROM drive with twice the pickup speed of a standard CD-ROM—which translates to less delay-time in a game—as well as a custom sound processor, a Macintosh-based multitasking operating system, and a 32-bit RISC processor CPU. The digital player will accommodate interactive pictures, audio CDs, and photo CDs. Expansion options will include a video-in port for home videotape editing.

3DO, the California-based licensing company for the player, is a partnership between four media conglomerates: Time Warner; Matsushita Electric Industrial Co.; Electronic Arts, a computer-game software giant; and Kleiner Perkins, a venture capital firm. The first machine will be available under the Panasonic name for about \$700.

—Marcelle M. Soviero

Digital volume control

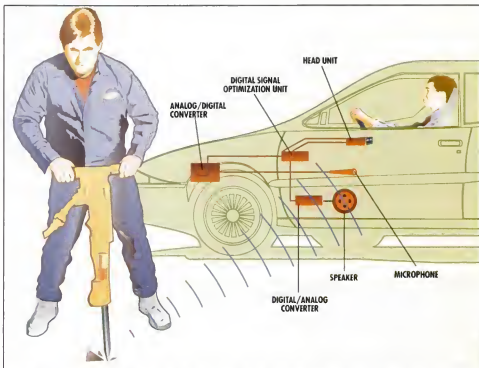
Highway noise often forces you to crank up the volume on your vehicle's audio system—but when you slow down, the sound from your radio or hi-fi system can be overwhelming.

Engineers at International Jensen Inc. (IJI) in Lincolnshire, Ill., have tackled this problem with an "audio-expert" system that tracks car noise and automatically adjusts the stereo's volume to compensate for it. Known as Dynamic Sound Optimization, the new system eliminates the need to readjust audio volume constantly.

While automatic volume control isn't new, IJI plows new ground with digital signal processing (DSP). This enables the system to discriminate be-

tween cabin noise and music by measuring inputs from both the stereo and a microphone in the vehicle's cabin. These signals are converted from analog into digital form and fed to a DSP chip. By monitoring the digitized signals for frequencies as well as volume, the DSP chip "knows" when it's listening to music.

The ability to discriminate between music and noise is a critical element, say engineers, because it prevents the system from overcompensating. In the past, such systems typically lumped



Digital-processing circuits in International Jensen's volume-control system compare music and noise inside a vehicle, automatically boosting or lowering music levels according to conditions.

noise and music together in a single measurement, then adjusted the stereo accordingly. The result: an audio system that battled against its own sound. The new system compensates only for objectionable noise.

That's a twofold improvement, say IJI engineers: First, the system provides effective yet unobtrusive volume control. Second, the audio signal is "shaped" slightly to compensate for the frequencies—as well as the volume—of cabin noise. The system blends the output so it sounds like the noise isn't there. "We're really just fitting the noise and music together," notes Ken Kantor, vice president of technology for IJI.

A key development is the "expert" software stored in the DSP chip. By monitoring the reactions of test listeners to environmental noise, engineers created a software model of human hearing and listening behavior. Thomas Miller, IJI senior research engineer, ex-

plains that "We're simply imitating the way people adjust their volume."

In a lab demonstration, the device lived up to its unobtrusive or "transparent" billing. Engineers played classical music along with taped car noises. Without the volume-control system, portions of the music were drowned out; with the system activated, all the audio could be heard.

IJI engineers foresee potential for the technology in home stereos, public music systems, telephones, and even in talking dashboard gadgets. Eventu-

ally the device will be integrated into automotive audio systems. Aftermarket versions may be available for less than \$250.—Chuck Murray

Computer-memory spin

A new memory device based on spinning hydrogen atoms could eliminate the data bottleneck that plagues parallel processor computers.

Rather than storing information in microcircuits etched onto silicon chips, MRAM—short for magnetic random-access memory—stores data in a frozen chunk of a secret, inexpensive chemical using nuclear magnetic resonance. Powerful MRI scanners that can "see" brain, muscle, and other soft tissue rely on the exact same technology ["Sharpest Look Yet Inside the Body," June '88].

The idea behind nuclear magnetic resonance is relatively simple. Subject water or a hydrogen-rich substance to

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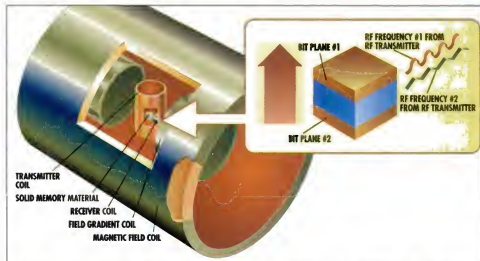
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Electronics Newsfront



Wire coils create a graduated magnetic field through a frozen solvent. Radio frequencies flip hydrogen atoms up and down in different solvent layers, writing or reading ones and zeros for digital memory.

an intense magnetic field and the hydrogen atoms line up, twirling like tops, with their axes of rotation pointed either up or down. Hit them with the right frequency radio wave and they flip upside down. "Up and down hydrogen atoms make perfect analogues for binary zeros and ones," says Gary Spletter, vice president of Sudbury, Mass.-based MRAM, Inc.

Memory devices based on this principle could be made from inexpensive parts—a common organic solvent that sells for \$20 per gallon, a walkie-talkie, and a car radio—and could theoretically allow tens or hundreds of processors simultaneous access to every bit of memory.

MRAM, which exists only in prototype, would work like this: A few cubic centimeters of the common organic compound, chilled solid, sits inside a magnetic coil where the field strength gradually increases from one end to the other. This magnetic gradation chops the memory into planes, or bits, with the hydrogen atoms in each plane spinning at a characteristic frequency.

To write to this memory, a processor tunes its radio transmitter to a particular frequency, then sends a signal that flips the hydrogen atoms located at this "address." Reading merely requires tuning the receiver to the required frequency and recording the phase of the signal, which distinguishes "up" hydrogen atoms from "down" ones.

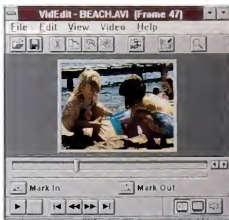
Since the connection between the processor and memory is wireless, adding processors is a snap, says Spletter. It also allows multiple processors to read the same bit simultaneously. "Data collisions," which occur when two processors try to write to the same address at the same time, can be eliminated by using an internal

clock that orders processors to write all zeros, then write all ones, then read all memory addresses.

Hydrogen-based memory systems have a number of advantages over today's memory chips: They're made for parallel processors, they don't need wired connections, and their production doesn't require expensive photolithography. Right now, though, data can only be written to MRAM at a sluggish 1,000 times a second, much too slow for usable memory. "We need to get the write speed up to the read speed—about 42 megahertz," says Spletter, a problem he believes can be solved. If so, commercial versions of MRAM could be available in three to five years.—P. J. Sherrett

Slice 'n' dice Windows video

At the software premiere of Video for Windows in San Francisco, a digital video clip showed a surfer riding the waves to a pounding beat inside a window on a PC screen. Then, Andy Grove, president of Intel Corp., sent



Software features within Microsoft's Video for Windows automatically scale image size and frame rate to the speed of playback hardware.


Microsoft chairman Bill Gates some "face mail" recorded with a video camera and embedded in a word-processing document. Later, in a scene from the movie *It's a Wonderful Life*, actor Jimmy Stewart—framed by scroll bars—begged for a second chance at life: "Please, God, let me live again!"

The files for full-motion digital video are just so massive that personal computers have a hard time ingesting them. That's why software engineers devise compression and scaling schemes—so that short video clips can be stored on a hard disk or CD-ROM and played back on a desktop PC. Apple Computer's QuickTime software has brought digital video to the Macintosh for more than a year. And last fall, Microsoft Corp. introduced its \$199 video software, delivering TV-like pictures for Windows applications.

Video for Windows employs Indeo, Intel's video-compression/decompression software that automatically scales the picture size and speed depending on the hardware being used for playback. A typical 386-based PC will display a video clip in a 160-by-120 picture-element window (inhabiting only about one-ninth of your screen), moving at a jerky 15 fps (frames per second). A 486-based machine, however, raises these blink-and-squint numbers to a quarter-screen-size picture and 24 fps, which is movie-theater speed.

Add an i750-based accelerator card and the same file can be viewed on a full screen at 30 fps (the same as television). Because video quality is automatically adjusted depending on the performance and computer configuration, the result is scalable video. You can also pick up the corner of a stopped video using your mouse and resize it; the resolution and frame rate adjust accordingly.

The Video for Windows package contains video playback and capture tools that you install under Windows 3.1 and a CD-ROM disc with some 250 video clips—each lasting only a few seconds but consuming one to two megabytes of disc space apiece. The collection's hodgepodge of activities ranges from lathe-working to bungee-jumping.

You'll need a video-capture board if you're planning to digitize your own moving images from a camera or videotape. Anticipated applications include video electronic mail, multimedia sales presentations, interactive training, technical documentation, multimedia encyclopedias, and interactive games.—*Michael Antonoff* 

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New device turns any electrical outlet into a phone jack

An engineering breakthrough gives you unlimited phone extensions without dangerous wires or expensive installation fees...

by Charles Anton

You don't have to have a teenager to appreciate having extra phone jacks. Almost everyone wishes they had more phone jacks around their house.

When I decided to put an office in my home, I called the phone company to find out how much it would cost to add extra phone jacks to my house—\$158!

No more excuses. Today, there are a thousand reasons to get an extra phone jack and a thousand excuses not to get one. Now an engineering breakthrough allows you to add a jack anywhere you have an electrical outlet. Without the hassle. Without the expense. Without the miles of unsightly wires.

What your mother never told you. Ma Bell never told you that you could use your home's existing wiring to transmit phone signals. Now you can add extensions with a remarkable new device called the Phonejak. It allows you to convert your phone signal into an FM signal and then broadcast it over your home's electrical wiring.

As simple as plugging in an appliance. Just plug the wireless Phonejak Transmitter into a phone jack and an electrical outlet. Then you can insert a Phonejak Receiver into any electrical outlet anywhere in your house. You'll be

able to move your phone to rooms or areas that have never had jacks before.

Phonejak gives you the

freedom of cordless telephone technology, without the cordless phone. Unlike cordless phones which transmit radio waves through the air, the Phonejak uses your home's electrical wiring to transmit signals, giving you sound quality which far exceeds that of cordless phones.

Clear reception anywhere in your home. Your range extends as far as you have electrical outlets. Five feet. Or five hundred feet. If you have an outlet, you can turn it into a phone jack—no matter how far away it is. You'll get crystal clear reception throughout even the largest of homes. (The

signal is terminated at your electrical meter so you can use your Phonejak in any electrical outlet in or around your home—even if they are on a different circuit.)

Unlimited extensions with no monthly charge. Most phone lines can only handle up to five extensions with regular phone jacks installed from the phone company. Not so with Phonejak. All you need is one wireless Trans-

mitter and you can add as many Receivers as you want.

Six, ten, there's no limit. And with Phonejak, you'll never have a monthly charge for your extra Receivers.

Works with any single-line phone device. This breakthrough technology will work for all of your single-line phone needs. It will operate your fax line, your answering machine and even your computer modem just by plugging them into your Phonejak Receivers.

This offer not available in stores. The wireless Phonejak System would carry a retail price of \$119 if it were available in stores. But through a special promotional campaign we are introducing this amazing technology direct to the public at substantially reduced prices!

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Is the Phonejak right for you?

The Phonejak is designed for use with any single-line phone device. Could you use one in your situation?

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- **Bad location.** You have jacks, but not where you need them.
- **Renting.** You want to add extensions, but you don't want to pay each time you move.
- **Other phone devices.** You have an answering machine, modem or fax you want to move to a more convenient place.



The wireless Phonejak utilizes advanced FM technology to make your home's electrical wiring "live" to phone signals, so you can plug in a jack anywhere you have an electrical outlet. One of the key components is the Phonejak

The Phonejak System. Includes a transmitter (right) and a receiver (left).

Transmitter, which links an existing phone jack to a nearby outlet. The Transmitter converts your phone line into an FM signal. The signal is transmitted through your home's wiring upstairs or down, regardless of distance. This one Transmitter can provide phone signals to an unlimited number of Phonejak Receivers which simply plug into any electrical outlet.

With the Receivers in place you're ready to add phones anywhere around your home for a lot less money and hassle than calling the phone company!



Science Newsfront

Edited by DAWN STOVER

Airport of the future

While aircraft have evolved from primitive biplanes to sleek jets, runways have changed little since the Wright brothers took flight. Now, finally, a licensed pilot named Jim L. Starry, who heads Environmental Protection Designs in Boulder, Colo., has reinvented the runway. His airport design, called Starport, could reduce energy use, air pollution, and noise.

Starry's simple design takes advantage of gravity: From the top of a 20-story terminal, planes roll down a sloping runway to gather speed for takeoff. On landing, they slow down by rolling uphill to the terminal, like an 18-wheeler barreling up a ramp for runaway trucks. "No one has done anything to make the runway control the aircraft," Starry complains. In Starport, the runways are slightly concave, to help planes stay centered, and are wide where the planes touch down, but narrow as they approach the rooftop gates. Passengers reach the gates by taking elevators from parking areas, shops, and restaurants in the terminal's lower levels.

Because the Starport runways would not be steep enough to bring planes to a complete stop, Starry has designed 800-pound brake-accelerator wheels that would not only slow planes on landing, but would also generate electricity as the wheels spin. The stored electricity could be used for taxiing. "From the moment you touch down, you could turn off the turbine," says Starry.

A 747 landing on a flat runway currently burns about 48 gallons of fuel when the pilot reverses the engines' thrust. Starry claims his redesigned wheels and runways could reduce the amount of fuel required for landings by about 25 percent—saving as much as 300 million gallons annually at an airport the size of Denver's new facility, which will open in late 1994 with 84 gates. The reduced fuel consumption would also improve air quality. (The diesel fuel burned while a jet's engines are idling is about 14 times more polluting



In this fuel-saving airport design, called Starport, planes land on inclined runways and coast to gates at the top of 20-story terminals. Planes get extra power for takeoff by rolling down the sloped runways.

than gasoline.) Noise pollution would decrease too, because on takeoff planes could coast 10,000 feet before switching to full thrust.

A Starport would require less land than conventional designs like Denver's new 53-square-mile airport, and Starry claims a Starport could be built using "off-the-shelf" highway overpasses. But although airport planners are reviewing his concept, none has yet been willing to build and test a Starport prototype.

Black hole?

Earth has an escape velocity of 25,000 mph. That means an object such as a rocket must attain at least that speed to escape the clutches of Earth's gravity and head out into space. The more massive a planet, the greater the force of its gravitational attraction and the higher its escape velocity. So the escape velocity of giant Jupiter, which has a gravitational force 350 times that of Earth, is about 133,000 mph.

Now imagine that somewhere in the universe exist objects so massive that their escape velocities exceed 186,000 miles per sec-

ond—the speed of light in a vacuum. But nothing can travel faster than light. Therefore, from such objects, there is no escape, not even for light. And with no telltale light emissions, such objects would be undetectable by direct observation.

On the basis of both theory and indirect observations, astrophysicists have long speculated that such objects, called black holes, do in fact exist. They are the remnants of collapsed stars so condensed that their gravitational pull is immense.

Now NASA's Hubble Space Telescope has garnered the best evidence yet for the presence of a black hole. It is the finest image ever of a disc of dust and cool gas—about 300 light-years across—that is being sucked into the nucleus of a galaxy in the Virgo Cluster, 45 million light-years from Earth. The nucleus, astronomers think, is the den of a black hole ten million times more massive than our sun.

"This is the first case," says Dr. Holland Ford, a Hubble scientist at Johns Hopkins University in Baltimore, "where we can follow the disc's gas in an orderly way down to the immediate environment of the black hole."

A co-investigator, Dr. Walter Jaffe of Leiden Observatory in The Netherlands, says: "We haven't seen a black hole itself. But it's as close to a black hole as we've ever seen before." —Arthur Fisher



A disc of dust and gas is being sucked into what may be a black hole.

BURIED SUNSHINE HEATS SPORTS CENTERS

BY P. J. SKERRETT

Can summer sunlight be stored for winter heating? The University of Massachusetts at Amherst intends to find out by building the first U.S. central solar heating plant with seasonal storage, or CSHPSS (pronounced chips). According to its proponents, seasonal storage makes it possible to use solar energy for heating during the short, cold days of winter in temperate and subarctic climates.

In its reverse form, the seasonal storage concept has been around since colonial days, when settlers routinely chopped blocks of ice from frozen lakes and packed them away in sawdust to cool food during the summer. Heating projects, on the other hand, only began to take shape after 1979. Since then, more than 30 pilot CSHPSS plants have sprung up in Sweden, Denmark, and other northern European countries.

The Massachusetts system, when it is completed in 1995 or so, will provide 90 percent or more of the space heating and hot water for a new 10,000-seat sports arena and an existing gymnasium. The two buildings require about as much heat as 150 homes, says senior research associate Dwayne Breger of the university's mechanical engineering department, one of the project's planners.

The system will work like this: Two arrays of south-facing, flat-plate solar collectors—with a total surface area of about 8,000 square feet—absorb sunlight and heat a mixture of alcohol and water. This antifreeze fluid is pumped to a heat exchanger, where it gives up its heat to water. The water then flows through hundreds of plastic pipes sunk into water-logged, nonporous clay, releasing heat along the way. During the summer, the 100-foot-deep clay deposit is expected to get as hot as 160°F. A

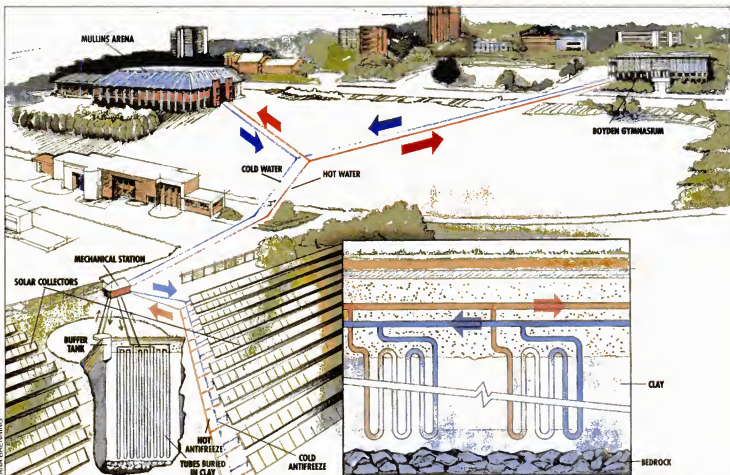
buffer tank that holds 250,000 gallons will store surplus hot water, which can be drawn off at night when the solar collectors shut down.

In the winter, water running through the embedded pipes will absorb stored heat and convey it to the arena and gym. Heat exchangers there will extract energy to provide hot water, and heat both buildings and a swimming pool. Once the \$3.5 million system is in place, the only additional cost will be about \$2,000 each year for electricity to run the pumps. Photovoltaics could eventually be used to supply this electricity.

"Basically, seasonal solar storage is the equivalent of a small power plant that doesn't burn anything," says Breger. It will probably work best for large office buildings, shopping centers, and heating systems linking 500 to 2,000 homes, because larger storage reservoirs lose proportionally less heat and tend to be more cost-effective.

Without seasonal storage, solar collectors don't match heating needs—the months with the best sunlight for generating heat are generally the warmest.

An ambitious CSHPSS project under way in the Swedish town of Lyckebo could ultimately serve a community of 2,000 homes and businesses. Water stored in a 100,000-cubic-meter cavern excavated out of bedrock absorbs heat from solar collectors perched on the rooftops of nearby homes, as well as waste heat from local industries. Inexpensive summertime electricity provides additional water heating. Eventually, the system will rely almost completely on solar and waste heat, according to Charles Bankston, a Washington, D.C., energy consultant who has worked on international CSHPSS programs for a decade. **MS**



Heated by solar collectors, antifreeze is pumped to a mechanical station, where the heat is transferred to water flowing through tubes embedded in clay (see detail). In winter, water pumped through the buried tubes absorbs heat and carries it to two sports centers to meet space-heating and hot-water needs.



About the size of a Mercury capsule, Lightcraft is powered by laser beams (red) relayed down from satellites orbiting Earth. Mirrors bounce the lasers to a pulse-jet engine (blue).

Mach 25 transporter

Sometime early in 2010, a passenger might take off from Albany, ride a one-person craft into space, and touch down 45 minutes later in Australia—all without burning an ounce of fossil fuel. Lightcraft, a concept vehicle designed by engineers at Rensselaer Polytechnic Institute (RPI) in Troy, N.Y., will be powered by lasers or microwaves beamed to it from satellites orbiting Earth.

Leik Myrabo, head of the RPI design team working on Lightcraft, says the vehicle will fill a niche: "Lightcraft will be a cheap, reliable way to send individuals around the globe or into orbit. Many of the components of the system were first developed for the Strategic Defense Initiative, and we are testing models of the craft and its engine right now."

Myrabo envisions a Lightcraft perched on its slender tripod landing gear, waiting for a satellite-based solar power station to come into position. When it does, it will relay laser or microwave beams to the upper surface of the craft. In the laser-driven version, mirrors on the Lightcraft will focus the beams under the vehicle, heating the air within a small area to 30,000°K. At this temperature, molecules of gases in the air explode, creating a series of blast waves that propels the craft up through the atmosphere.

When the craft reaches Mach 11 (8,000 mph) and 90,000 feet, it will switch to magnetohydrodynamic propulsion ("Superconductivity Goes to Sea," Nov. '92). In the upper atmosphere, the air is too rarefied to detonate, but there will still be enough propulsive force to create a shock wave as the craft zooms upward. Two rings of superconducting magnets and a laser-to-electric-power converter will

accelerate the glowing air plasma behind the shock wave, blowing it backward to boost the craft to its orbital velocity of Mach 25. The converter uses a small amount of liquid hydrogen—the only fuel Lightcraft carries.

The RPI team has already tested the liftoff pulse-jet laser-powered engine at the Naval Research Laboratory in Washington, D.C. The result: performance equal to the jet engines of 1942. "We need to bring our thrust-to-power ratios much higher," admits Myrabo, "but for the very first test of a new design, we think this shows great promise." An unmanned demonstrator could be tested within five years. —Jonathan D. Beard

Preserving biodiversity

One of the most pressing global problems is the ongoing loss of plant and animal species resulting from human activities such as deforestation. Now there is a new program to help counter this threat. The International Cooperative Biodiversity Groups Program will encourage the preservation of disappearing ecosystems and the production of new drugs—including anticancer drugs—from natural products.

The biodiversity program is cosponsored by the National Science Foundation, the U.S. Agency for International Development, and the National Institutes of Health. They will jointly award grants to international organizations, who will collect and inventory plants and other organisms from endangered ecosystems such as rain forests, coral reefs, and deserts. The awards will also help developing nations to conserve their own biodiversity.

Recent examples of "miracle drugs" derived from plants are taxol from the Pacific yew tree of the northwestern United States, and vincristine and vinblastine from the rosy periwinkle of the Madagascan rain forests. —Arthur Fisher

Sneaker spill

A pair of oceanographers in Seattle have turned a minor maritime mishap into a major effort to study ocean surface currents.

The accident occurred in May 1990, when a freighter en route from Korea to Seattle encountered a severe storm and

dumped part of its cargo overboard, including 80,000 Nike sneakers. Eight months later, beachcombers in the Pacific Northwest began finding the waterlogged—but still wearable—floating footwear.

Oceanographer Curtis C. Ebbesmeyer, who is currently researching a book on floating objects in the North Pacific, read about the spill in 1991. "I've been studying drift bottles," he says. "The biggest study I knew of consisted of 150,000 bottles released in various locations over a ten-year period. So I knew that 80,000 objects released at once could be very interesting."

Ebbesmeyer and W. James Ingraham Jr., an oceanographer at the National Oceanographic and Atmospheric Administration in Seattle, tracked down more than 1,600 sneaker sightings. They have used the information to test computer models of ocean currents. When Ingraham simulated the spill using a model that accounts for wind-generated surface currents and the effect of Earth's rotation, it predicted that the shoes would arrive first at Vancouver Island. The computer model missed by just 50 miles.

Ebbesmeyer and Ingraham are continuing to track the great Nike sneaker spill of 1990. Footwear that did not wash ashore may have entered a huge circular current called the Great North Pacific Gyre. "Some of the shoes are going to make this loop around the Pacific," says Ebbesmeyer. "I have a few reports from Hawaii, and they'll probably be showing up in the Philippines soon." He also expects that by the fall of 1994, some of the sneakers will pass near the spot where they first plunged into the water. —Todd Campbell



Science Newsfront

Affordable caviar

Scientists at Israel's Technion Institute have invented a substitute for sturgeon caviar, a luxury of the rich that costs \$30 to \$40 an ounce in the United States. Alexei's Caviar-Like, as the new product is called, can be purchased in Israeli supermarkets for less than \$2.50 an ounce.

A team led by Alexander Gelman, a biochemist specializing in fish, makes Alexei's from a patent-pending combination of fish fats, vegetable fats, salt, water, and natural preservatives and stabilizers. A cylindrical machine that looks like a mortar launcher forms the ingredients into caviarlike "eggs" that are the same size and grayish color as authentic beluga sturgeon roe.

Alexei's is produced strictly according to Jewish dietary laws. Because most real caviar comes from non-kosher sources like sturgeon and lumpfish, Alexei's has opened the caviar market to kosher consumers.

Health-conscious consumers may also be interested in Alexei's: It has less cholesterol and fat than real caviar, and just one-fourth the calories. And

unlike real caviar, which becomes runny and loses its color and taste at high temperatures, Alexei's can be cooked or microwaved without deterioration. This means that not only can it be served in the traditional manner with chilled vodka or iced champagne, but also in omelets, as a pizza topping, or even in processed cream cheeses. "We are opening an entirely new market for caviar products," proclaims Gelman.

Along with biochemist Uri Cogan and food production equipment engineer Ze'ev Mager, Gelman formed Delitech Ltd. in 1988 to produce Alexei's. The caviar substitute is now available in Israel. In the United States, Delitech is represented by Gourmets Ltd. of Englewood, N.J. —*Wordservice International*

Speedy sensor

For researchers devising the Lilliputian electronics of the future, glass has two desirable properties: Like hot candy, heated glass can be twisted and pulled into all sorts of shapes. Moreover, it transmits light—the fastest possible way to send a signal.

At the University of Michigan in Ann Arbor, chemist Raoul Kopelman is taking advantage of both properties to build sensors that measure pH, or acidity, with "business ends" as small as 20 nanometers—20 billionths of a meter. That's more than a million times smaller than previous pH sensors made from optical fibers.

For the first time, "you can put a sensor inside a cell and measure [pH changes] while the cell is still alive," says Kopelman. This could have important medical applications. In fact, Kopelman's team has already verified that a chemical suspected of causing birth defects in pregnant women causes drastic changes in rat embryos. Moreover, with a response time of one-fiftieth of a second, the sensor may be speedy enough to catch brain neurons in the act of firing.

To make the sensor, Kopelman first stretched glass fibers into extremely thin cylinders, using a laser technique developed at AT&T. Then he applied an opaque aluminum coating to everything but the tip. And finally, he attached to the tip a fluorescent polymer that glows with different colors de-

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pending on the acidity it encounters. When the tip is inserted into a sample, the light travels to the far end of the glass, where it is translated into a pH reading.—Robert Langreth

Bargain fighter

Sweden's Saab JAS 39 Gripen fighter, now undergoing final flight tests before the first planes are delivered to Swedish air force training units, is attracting attention from possible export buyers. Even Germany considered buying the Gripen as a substitute for the European Fighter Aircraft (EFA) project, which it had started in 1985 with Britain, Italy, and Spain. Germany wanted a cheaper fighter, but finally compromised on a stripped-down New EFA (NEFA). Even so, the cost of each NEFA will be well over \$50 million.

The Gripen fighter is much less expensive, costing less than \$30 million. Its most remarkable feature is its size: It is the smallest, lightest fighter to go into production since the early 1960s. Fully loaded, it weighs eight tons—about half as much as the EFA



Sweden's Saab JAS 39 Gripen, under development for a decade, is nearly ready for service. The Gripen is much smaller and less expensive than other modern fighters.

and little more than a quarter as much as the U.S. Air Force's Lockheed F-22 Advanced Tactical Fighter ["Fast, Agile, Stealthy Supercruisers," April '91].

The fighter is small because Swedish planners realized, when the project started in 1982, they could not afford a big fighter and that more accurate, more reliable bombs and missiles would allow a fighter to be just as

effective with a smaller weapons load.

The Swedish airplane uses less fuel than bigger fighters, and it was designed for easy upkeep, because in Sweden, conscripts do most of the maintenance. Because of this, its makers claim that the Gripen will cost about \$3,000 per hour to fly, no more than a medium-size business jet. Most fighters cost that much in fuel alone.—Bill Sweetman

ES



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Home Newsfront

Edited by MARIETTE DiCHRISTINA

Flights of terra firma

When Jonathan Zimmerman inflates a balloon, it isn't for a flight of fancy. The San Francisco architect uses balloons of fiberglass-reinforced nylon or other fabrics to form his sturdy, energy-efficient structures.

After the balloon is inflated, the inside surface is sprayed with rigid polyurethane foam insulation (see photos). Steel reinforcing bars are then tied into place against the insulation, and concrete is sprayed to cover the steel. Door and window openings are created by leaving out the steel reinforcements and concrete and cutting away the insulation. Later, the balloon can be coated with the desired color or texture, and earth can be bermed against the structure.

Zimmerman says that the design should yield a skin with an insulative value of R-32, though it hasn't been formally tested. He also claims that his air-forming can cost half the price of a conventional building shell: "Balloon-shell costs are

between \$25 and \$35 per square foot of base area, and that is for a container that can hold more than one floor."

Like geodesic domes, the lack of corners makes air-formed homes more earthquake- and wind-resistant than conventional structures are, says Zimmerman. And the insulation is built into the structure, so it does not need to be added. Air-forming also permits compound shapes to provide greater design flexibility than geodesics, which are made of triangles or other shapes that generally create part of a sphere.

Chief among the obstacles to acceptance of the air-formed structure, says Zimmerman, "is that it doesn't look like anything else. It doesn't have the normal cultural antecedents we look for when we buy a house, the symbol of our success. So we're perfectly happy to buy the [conventionally designed and built] energy lemon, because it makes the statement that we have been expecting to make: 'I have arrived.' The question is, where is that?"



Inflated to a complex double curve, a balloon forms the shape of a house built in the Rockies. Steel reinforcing bars (left) are fastened to insulation sprayed inside the balloon. Concrete then covers the bars.



Monthly electric heating bills for this 3,400-square-foot house have not exceeded \$30.

Though the compounds are still being tested, Worley says they will work well for pools and households. "One compound in particular could be used in the home," says Worley, "sprayed onto a surface from an aqueous solution. The protective film would disinfect and prevent surface contamination of such places as the kitchen floor or bath for a long time."

In pools, the compound would decompose more slowly in sunlight than conventional chemicals. The compounds withstand higher temperatures as well, making Worley's disinfectants suitable for use in hot tubs. —Patricia Barnes-Svarney

Pure protection

Nontoxic compounds first developed to protect eggs against bacteria could soon work as pool and household disinfectants too. The inexpensive compounds, developed by researchers at Auburn University in Alabama, kill bacteria and algae.

"We've developed a series of new N-halamine disinfectants," says S. D. Worley, professor of chemistry at Auburn. "Most [currently available compounds] kick the chlorine off the nitrogen and into the water. The chlorine kills the bacteria but it's also corrosive and disappears when it reacts with impurities or through evaporation loss." Worley's compounds contain one or two nitrogen atoms in five member rings, with the chlorine tightly bonded to nitrogen atoms. Because of this superbond, the compounds themselves kill the bacteria, rather than the chlorine breaking away. And since the chlorine stays bonded, there is less corrosion, fewer reactions with impurities—and less of that otherwise-familiar chlorine smell.

Stain-eating enzyme

Stubborn laundry stains may soon meet their match in an enzyme made by bacteria from marine shipworms. The enzyme, which may aid digestion for the shipworms, breaks down proteins in stains such as blood, grass, and milk.

Discovered by John Waterbury at Woods Hole Oceanographic Institute in Massachusetts, the unnamed bacteria lives in a gland of the shipworm, a saltwater mollusk that can grow out of its bivalve shell to lengths as long as six feet. Both the enzyme and applications for it were developed by Harold L. Griffin, Richard V. Greene, and Michael A. Cotta, researchers at the U.S. Department of Agriculture.

These Agricultural Research Service scientists developed a fermentation "broth" to keep the bacteria alive and producing the enzyme. The enzymes work in the harsh conditions of warm and cold wash water that is made alkaline by the new nonphos-

Home Newsfront

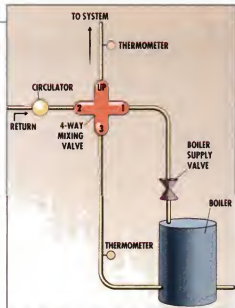
phate laundry detergents. Such hardness could make the enzyme a candidate for other processes that require proteins to be degraded in harsh environments, such as recovering silver from photographic film, cleaning contact lenses, or removing hair from hides to be made into leather.

Mixing up a steady heat

Variety may spice up your life, but you'd be better off keeping it out of your heating system: It's the steady, even temperatures that bring comfort. Just a two- or three-degree-Fahrenheit swing to either side of the thermostat's set point may make you feel uncomfortably cool or warm. Newer, more sensitive electronic thermostats help moderate these temperature swings, but they don't prevent the ba-

sic "on-again, off-again" approach that lies at the heart of this problem.

In hot-water systems, however, a few progressive heating contractors are beginning to use special mixing valves to produce more consistent heat. Long used in Europe, the valves are relatively new in the United States. By tempering hot boiler water (typically 160°F to 200°F) with cooler water from the system's return pipe before sending it to the radiators, the mixing valve lets a hot-water system work in a fundamentally different way (see illustration): Instead of intermittently sending very hot water through the radiators, the system constantly adjusts the supply water temperature and circulates it continuously. Thus on mild days, the water flowing through the radiators may only be 100°F, while in sub-zero weather it might be 180°F.



In this heating system, an electronic "black box" controls a mix of boiler water and return water to make temperatures more even.

WEIRD NEW SAW BLADES: CAN THEY CUT IT?



From the left, the uniquely shaped teeth of Marathon, TK, Tracker, Piranha, and Lightning blades cut better and longer than other blades.

Several of these strangely contoured new saw blades are now available—but are they better? To find out, I tried 7- to 7½-inch general-purpose blades, which fit almost all portable saws. My test subjects: the Black & Decker Piranha, Freud TK, Vermont American Lightning, Irwin Marathon, and Oldham US Saw Tracker blades.

Creators of these blades say their designs have further enhanced cutting ease and blade life, while decreasing the tendency toward kickback. To do this, they take a variety of approaches.

For example, the TK, Marathon, and Tracker blades have risers in the gullets to limit chip size, preventing kickback. While most saw blades have a 5- to 20-degree tooth hook angle, the Piranha has a more aggressive, curved "fishhook" grind on the tooth face that creates a hook angle of about 30 degrees. Lightning and Tracker blades have hook angles of about 36 degrees. The strategic placement of blade cooling and expansion slots also improves durability.

The saws also employ smaller carbide-grain sizes, which increases hardness and abrasion resistance, though brittleness is a

potential side effect. Vermont American, for example, combats this in its patented Dyanite process by injecting a small amount of boron into the carbide, says corporate metallurgist Zane Lockhart. "Boron significantly improves the saw teeth's resistance to fracture without decreasing hardness or increasing brittleness."

Ripping, cross-cutting, and mitering, I tried the blades extensively on a variety of materials: studs, plywood, particleboard, and treated deck lumber. These "thin" or "micro-thin" kerf blades are by nature faster because they don't have to remove as much wood; averaging under ⅜-inch kerfs, they make a cut that's 25 to 35 percent narrower than conventional carbide blades.

All of the blades generally made smooth-surfaced cuts, but they still fuzzed up the top surface of plywood at the kerf (a common problem with anything but the special fine-toothed plywood blades). The Lightning, Tracker, and Piranha blades cut particleboard, studs, and plywood faster, while the TK, Piranha, and Lightning seemed fastest in treated wood.

All of the blades that I tried out cost somewhere between \$8 and \$15. That's really not much more than a good steel saw blade, and carbide stays sharp up to 50 times longer. —Phil McCafferty

At 100X magnification, the Lightning blade shows far less wear after 5,000 feet of cutting than a conventional carbide blade.



This approach can keep a house's temperature within one degree of the set point, which significantly increases occupant comfort.

This approach also offers modest energy savings (usually less than 10 percent), a reduction in corrosive flue-gas condensation, and the ability to tie a radiant floor zone (which, even at peak loads, requires relatively cool water temperatures in the low 100s) to a fin-tube radiator distribution system (which requires peak water temperatures of up to 200°F).

These benefits will run you about \$800 to \$1,000 for parts, plus labor—about a day's work for an experienced contractor. Suppliers include: TekMar Control Systems, Ltd., 4611 23rd St., Vernon, B.C., Canada V1T 4K7; Honeywell Centra, Customer Assistance Center, Box MN 27-2164, Honeywell Plaza, Box 524, Minneapolis, Minn. 55440.—David Dobbs

Lead-less fixtures: update

By now, the damaging effects of even minute quantities of lead on humans are well-known. Exposure to the metal has been linked to brain and nerve damage in children and high blood pressure, severe anemia, and kidney damage in children and adults. Recently AT&T Bell Labs of Murray Hill, N.J., was awarded a patent that could help reduce lead exposure in the home: a brass alloy for plumbing fixtures that requires no lead.

To improve machinability, brass alloys contain 3 to 7 percent lead. The new alloy, however, replaces lead with bismuth and small amounts of other additives ["Home Newsfront," Sept. '91]. To confirm its

To the Rescue!



Shown smaller
than actual size
of 8 1/4" in diameter

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Sparky®

By Marty Roper

**A numbered limited-edition
collector plate trimmed with 23kt gold**

Clang! Clang! Clang!... the bell sounds. This time, *Sparky's* determined—they'll just have to let him come along on the fire truck! So he dons his special hat and red bandana and grabs a fire hose, ready to race to the fire. But the firemen are nowhere to be found. Then *Sparky* realizes...it's not a fire alarm...it's the twelve o'clock whistle. Time for lunch!

Now, award-winning animal portrait artist Marty Roper captures *Sparky's* unique character and spirit on a limited-edition porcelain collector plate. Roper's paintings reflect a genuine love for his canine companions.

A Limited Edition

Sparky is appearing on a collector plate for the first time and is available exclusively from the Danbury Mint. Each numbered plate will be trimmed with a band of 23kt gold and accompanied by a personalized Certificate of Authenticity. The edition will be limited to 75 firing days, and the price is just \$26.95.

No Obligation—No Risk

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The wonderful colors and lifelike detail found in Marty Roper's work make *Sparky* a collector's dream. To avoid delay, mail your order today!

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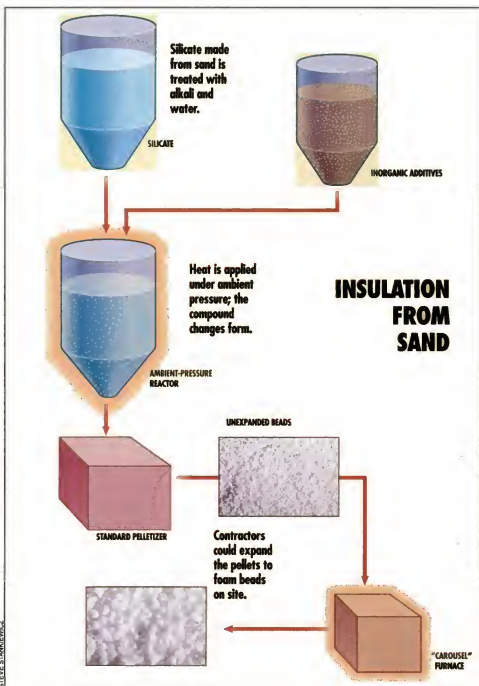
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Allow 4 to 8 weeks for shipment.

FDP

06



machinability, Kearny Smelting and Refining of Kearny, N.J., has prepared some small samples of the lead-less alloy. "In addition," explains Michel Rothschild, president of the company, "we recycled the alloy several times, with no difficulties."

Heat, cool—and hot water

There's a certain inescapable logic to triple-integrated heat pumps: If you can use one device to heat and cool your house, why not add efficient water heating as well? The new Powermiser heat pump does just that—and for less money than other units, claims the manufacturer.

In summer, a heat pump works like an air conditioner, using refrigerant to convey indoor heat outdoors; a revers-

ing valve switches refrigerant flow for winter heating mode, to bring heat derived from outdoor air indoors.

Developed by Nordyne of St. Louis and the Electric Power Research Institute in Palo Alto, Calif., Powermiser has many of the features of the more-advanced Carrier HydroTech 2000 ["Do-It-All Heat Pumps," Nov. '89; "Best of What's New," Dec. '89]. Like the HydroTech, for example, Powermiser can heat hot water in any mode. Other integrated systems heat water via a desuperheater, which draws excess heat from refrigerant during cooling mode.

In cooling mode, Powermiser uses excess heat from the refrigerant to heat water for "free." During winter, the unit extracts heat from outdoors for water- and space-heating. When

the heat pump isn't heating or cooling, it warms water by gathering heat from outdoors or from indoor humidity. A patented control system adjusts the refrigerant charge to meet various conditions, so there is no overcharging during times of lower demand.

Wayne Reedy, Nordyne's president, says Powermiser costs about \$1,000 more than units with no built-in water heating; HydroTech costs some \$4,000 more, says Carrier. Using a mechanical control system rather than a microprocessor is one way Powermiser costs are reduced, says Reedy. Another way is that, unlike the variable-speed HydroTech, Powermiser is single speed.

Powermiser has an efficiency rating of 10 SEER, or Seasonal Energy Efficiency Ratio (HydroTech is more energy-efficient). Although there is no accepted way to credit energy savings from water heating, Reedy says that to get equivalent savings a conventional heat pump would need a SEER of about 18. A 12 SEER Powermiser will be sold this spring.

Beads of insulation

It's inert, made from sand, and when heated expands to foam beads that are 25 times their original size. It's Cylofoam, an experimental insulation.

"It looks like Styrofoam, but is totally inorganic," says Raymond T. Ertle, president of Cylatec Corp. of Pompton Plains, N.J., which makes the foam. "We start with a silica sand that is converted to silicate with heat and alkali," he says (see illustration). Silica and sodium carbonate are dissolved in a digester to produce the silicate, or water glass. The liquid is then converted to dense sandy particles in a process that Ertle is seeking to patent.

Unlike foams that require ozone-chewing chlorofluorocarbons to expand, Cylofoam uses heat. The particles are baked on-site in a patented "carousel" furnace. The furnace, which is small and could be mounted on a truck, turns them for even heating until they expand 25 times. Expanding the material on-site saves trucking costs, says Ertle. He adds that the furnace has also simplified the process of expanding silicate, which used to require "long periods of hydration and drying."

Tests by the Oak Ridge National Laboratory in Tennessee showed that the insulation's resistance to heat flow is about R-4 per inch, depending on density, says Ertle. He adds that Cylofoam reacts with gypsum to form a ceramic, making it withstand tempera-

tures of 1,200°F to 1,500°F before melting. Mixed with gypsum, it would thus make fire-resistant wallboard. Other potential applications include its use as a low-density concrete aggregate.

Notes from home

•Although recycling is of vital importance, says Keep America Beautiful, it's not enough to solve garbage problems. A free booklet from the organization, "Recycling Realities: Facts, Myths and Choices," explains recycling's place in managing garbage and covers other options to handle waste safely. Address: 9 W. Broad St., Stamford, Conn. 06902.

•Pilot production of titanium dioxide photovoltaic cells, transparent solar cells that could someday be used in windows, will soon begin at the Swiss Federal Institute of Technology in Lusanne ["Best of What's New," Dec. '92; "Home Newsfront," March '92]. Asea Brown Boveri of Baden, Switzerland, is developing commercial fabrication methods, while Sandoz Chemicals of Basel is working on the

synthesizing and testing of new dyes.

•To introduce frost-protected shallow foundations, the National Association of Home Builders Research Center is currently building three demonstration projects. The foundation method saves energy in cold climates and is less costly to install ["Home Newsfront," Aug. '92; "Best of What's New," Dec. '92]. One house with the shallow foundation has been built in Williston, Vt.; two others will be installed in houses that are being constructed in

Fargo, N.D., and in Spirit Lake, Iowa.

•Seeds for those tennis-ball-size heads of mini iceberg lettuces ["What's New," March '91] will be available to the home gardener this spring, says the Agricultural Research Service.

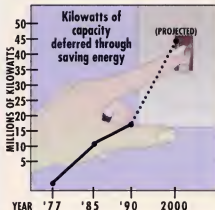
•A biodegradable plastic that's made from sugars by the British chemical giant ICI is being sold commercially in the United States for the first time. The plastic, Biopal, forms the bottles for Evanesce shampoos and conditioners.

For hard-working men, boots that earn their keep.



Our famous Texas Steer 6" Nubuck Leather Boots have all top-grain leather uppers. Lightweight oil-resistant outersole. Tough Goodyear® welt stitched construction. Extra-soft padding for added comfort. Only \$39.99. Available only at Kmart. The quality you need, the price you want.

SAVE A (KILO) WATT



Turn off the lights when you leave a room. Reset the air-conditioner thermostat to 78. By now, these energy-saving maxims seem old hat. What may be surprising, however, is how much power such measures have actually saved.

Faced with rising demand—and the even greater difficulty and expense of building new plants—electric utilities began "demand-side management" programs two decades ago. In 1977, there were 134 such efforts aimed at educating consumers to save energy; today there are more than 1,500, says the Edison Electric Institute, a trade association. The resulting energy savings have deferred the need for 20 million kilowatts—the equivalent, says Edison Electric, of 42 average-size power plants that didn't have to be built.



TEXAS STEER



Live in the lap, lap, lap, lap, lap, lap, lap of luxury.



At Nissan, we understand that a day filled with water balloon fights, temper

tantrums and potty training, can give any parent jagged nerves.

Which is why everything in the new Nissan Quest[™] has been designed to soothe and pamper.

Your fingertips settle on a steering wheel graced with



fine leather.* Your eyes gaze at easy-to-read analog instruments.



And your ears are lulled by an advanced AM/FM audio cassette system.*

Cruise control[†] and an optional sunroof^{***} are available so you can concentrate



And since we know how much kids enjoy playing musical chairs, we designed our QUEST TRAC[†] Flexible Seating System to be reconfigured up to 24 different ways.^{††} In fact, you can remove the second row and by simply flipping a lever you can slide the third row into five different positions along the QUEST TRAC.

Which means with the new Nissan Quest a parent can finally sit back and relax until, that is, your kids start making faces at the car

on the scenery instead of the speedometer. Attention to ergonomics is so complete that the controls to the power windows, door locks and mirrors are nestled in

the driver's side door.[†] Of course we intend to spoil your children as well.

A second row of luxurious captain's chairs^{**} is provided to keep your kids

from squirming about. To keep them entertained, the second row even has its own set^{**} of air conditioning controls, headphone jacks and audio controls.

behind you.

The New Nissan

Quest



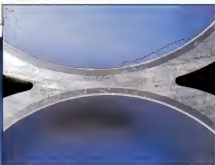
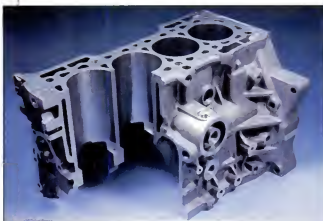
*It's time to
expect more from
a minivan.**



wear their seat belts. *GXE model **Optional on GXE model †Optional on XE model, standard on GXE. ††GXE with optional 2nd-row captain's chairs.

Automotive Newsfront

Edited by DAN McCOSH



A bundle of fibers is cast in place to line the cylinder walls of Honda's new Prelude engine. Because of its strength, the system can use thinner cylinder sleeves (above).

Honda's metal matrix

Embedding carbon or aramid fibers in plastic resin to make strong composite materials is considered commonplace nowadays. Even sporting goods—which don't always need such exotic structural contents—can boast of them. But how about lacing a motor with nonmetallic fibers?

Honda Motor Co. is using a fiber-reinforced metal alloy, also known as a metal-matrix composite (MMC), to help make high-performance engines lighter and smaller. It's currently used to line the cylinders of the 2.3-liter Prelude engines sold in the United States. Honda's MMC is made from aluminum alloy reinforced with short lengths of carbon and aluminum-oxide ceramic fiber.

The ultrahard ceramic fibers prevent the sliding piston rings from contacting the softer aluminum matrix surrounding them. This improves the wear-resistance of the cylinder liners. Carbon fibers are also added for their self-lubricating characteristics. Together, the two types of reinforcing fibers compose 24 percent of MMC by volume.

The hybrid material's greater strength when compared with conventional cast-iron cylinder liners enabled Honda engine designers to reduce cylinder wall thickness from nine to seven millimeters. The payoff is a weight savings of ten pounds, plus an increase in engine displacement with no change in exterior dimensions. A further benefit is MMC's superior thermal conductivity, which improves heat transfer from the cylinders, according to Ben Knight, vice president at Honda Research and Development North America in Torrance, Calif.

Honda's MMC isn't the only route to stronger and lighter aluminum engines. Porsche and Mercedes cars and the ill-fated Chevy Vega have all used engines cast from a tough high-silicon alloy developed by Reynolds Aluminum. The disadvantage with a

high-silicon alloy is extreme surface hardness, which eats up lots of expensive cutting tools during the machining process. Honda must use a special diamond-tipped hone to finish its MMC-lined cylinders, but the rest of the block is machined using standard tools.

In developing the MMC casting process, Honda's engineers borrowed a method used in traditional papermaking. A slurry composed of water and the two types of fiber is drawn by suction through a cylindrical screen, which traps the carbon and ceramic whiskers on its surface. The resulting preform is then compressed to increase its density and fired in a kiln, destroying the screen.

During the low-speed die-casting process used to make Prelude engine blocks, molten aluminum is forced into

PREVIEW DRIVE

GMC GOES AERO WITH '94 SONOMA



The 1994 GMC Sonoma that was previewed this spring is new down to its frame. The design, with a radically bobbed nose, raked windshield, streamlined cab, and neatly integrated rear bumper, results in a 0.42 coefficient of drag (for the two-wheel drive)—amazing for a pickup—down from the current 0.475.

The reshaping, along with improved door and body sealing and other detail improvements, significantly reduces wind noise. The intrusion of outside noise is reduced by increased sound insulation, quieter engines and transmissions, and smaller body openings. The interior is also revamped,

with additional hip-, shoulder-, and leg-room, as well as more comfortable seats and a more contemporary dashboard.

A stiffer frame on two-wheel-drive models provides a more solid feel. Seven suspension/shock/tire packages have been developed to match customer use.

A short ride in a five-speed-manual V6 Sonoma preproduction model with "sport" suspension verified GMC's claims, indicating that the '94 Sonoma should be as tough a competitor as it is a truck. But don't look for it at your GMC dealer until regular 1994 model introduction time.

—John Matras

PORTRAIT OF A QUITTER



About six years ago, I decided to stop smoking. So I tried cold turkey. But soon, my wife caught me sneaking cigarettes out the bathroom window.

QUITE FRANKLY, I NEVER THOUGHT I COULD REALLY QUIT SMOKING.

Then my doctor suggested Habitrol™. Habitrol is a nicotine patch, indicated as an aid to smoking cessation for the relief of nicotine withdrawal symptoms. It's available only by prescription. When used as part of a comprehensive behavioral smoking cessation program, it's been clinically proven to increase the chances of quitting in the critical first three months. That's when nicotine withdrawal symptoms force many people back to smoking. Long term studies with Habitrol haven't been conducted.

As part of my smoking cessation program, I attended a support group my doctor recommended. He also gave me a free support kit with tips on getting through the rough times. And an audio tape for relaxation and motivation.

Because Habitrol contains nicotine, STOP smoking completely before starting your therapy with Habitrol and do NOT smoke or use any other nicotine containing products while you are receiving Habitrol therapy. If you're pregnant or nursing, or have heart disease, be sure to first find out from your doctor all the ways you can stop smoking. If you're taking prescription medicine or are under a doctor's care, talk with your doctor about the potential risks of Habitrol. Habitrol hasn't been studied in persons under 18, and it shouldn't be used for more than three months.

If you're really determined to quit, ask your doctor if Habitrol as part of a comprehensive smoking cessation program is right for you. Or call 1-800-YES-U-CAN, for a brochure today.

If you're tired of quitting and failing, Habitrol can help you with the nicotine craving and this can help you in your program to quit smoking. After that, it's up to you.

IF YOU'VE GOT THE WILL, NOW YOU CAN HAVE THE POWER.

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See next page for additional important information.

273-30880

Habitrol™
(nicotine
transdermal
system)

Automotive Newsfront

the tiny voids in the fiber cylinder-liner preforms. The solidified engine-block casting is a complex chunk of metal with extra-hard bores and easily machinable surfaces everywhere else. Using the MMC process for the medium-volume Prelude engines increases Honda's manufacturing cost by about \$100 per car, a price that so far has restricted its use to the Prelude engine. —Stuart F. Brown

Safety headlights

High-beams that don't blind oncoming drivers and can penetrate fog are the promise of ultraviolet (UV) headlights being promoted in Sweden by Ultralux, a joint venture backed by Volvo and Saab.

While invisible to approaching

drivers, UV illuminates fluorescent objects such as specially treated road markers, clothing, and other articles, making them glow in the dark like nylon shirts in a disco. Since the UV light isn't visible when reflected by water droplets, it drills through fog and mist with no white-curtain effect and can even penetrate an inch or two of snow. The concept isn't new, but eliminating the known health hazards of UV puts it closer to acceptance as a practical safety aid.

The headlamp assemblies used by



Ultralux's new ultraviolet headlamp system being tested in Europe illuminates fluorescent objects such as specially treated clothing (right).

Ultralux are supplied by Hella in Germany. The system uses high-intensity gas-discharge (HID) bulbs that have UV in their spectrum. UV light is below the wavelength of visible light. Visible light is eliminated with a blue glass filter in front of the bulb reflector. Of the three types of ultraviolet radiation, UVB and UVC can cause cancer and eye damage, and their short wavelengths are suppressed by careful color-tuning of the filter.

This leaves relatively harmless UVA, commonly used in tanning lamps, which is just below the visible light band. Since there is still a possible health risk to children who are attracted by the faint violet glow and peer into it when the car is stationary, Hella proposes that these headlights be usable only when the vehicle is moving.

Ultralux has prepared 50 miles of public roads around Gothenburg, Sweden, with fluorescent markings and signs as a testing area. It is running tests with four-eyed cars that have normal halogen dipping, or low-beam, lights paired with high-beam UV units on each side, which is the expected layout for future applications. The UV lights automatically come on with the white dipped beams, effectively doubling their range without causing dazzle.—David Scott

Friendly advice

Instead of just showing a recommended route on a screen, Toyota's new Global Positioning System has a polite female voice to guide you through every turn.

On a recent test drive in Japan, the system figured the best route to my input destination and displayed it on screen. Then the voice took over. The spoken directions led me out of Tokyo, down some 65 miles of highway including interchanges, through suburbs, and into the heart of a city I had never visited before. I literally could have done it without glancing at the screen or reading the road signs.

Once on the highway, the voice says

P R E V I E W D R I V E

WEIGHT-WATCHER'S SUPRA

You won't find all-wheel drive, four-wheel steering, or "active" aerodynamics on Toyota's 1993 Supra, the company's flagship car. All were omitted during the development of the fourth-generation Supra as part of a strict weight-reduction regime. In the process, Toyota's "willpower" team met some 950 times to come up with weight-saving features such as an aluminum hood, plastic gas tank, a single-rather than a dual-exhaust system, hollowed-out bolt heads, and even hollow-fiber carpeting for the car's interior. It all adds up to a 310-pound savings in weight and brings the Supra's gross vehicle weight to about 3,200 pounds for the base model. That approaches the 3,000-pound weight of Acura's all-aluminum NSX in the super-car class.

Indeed, the new Supra is no lightweight in performance. The base engine, a three-liter double-overhead-cam in-line six from the Lexus SC 300, produces 220 horsepower at 5,800 rpm and powers the rear wheels through a five-speed-manual or four-speed-automatic transmission. The twin-turbo version—the primary turbo pro-

vides the boost below 3,000 rpm and the primary and secondary supply the boost above 3,500 rpm—delivers 320 hp, sufficient, says Toyota, to get the car to 60 mph in 5.1 seconds. Top speed is limited to 155 mph by the engine computer. A six-speed manual is standard and a four-speed automatic with manual-shift mode is optional on the turbo.

Four-wheel-independent double-wishbone suspension, front and rear stabilizer bars, and massive Z-rated tires (the base model gets 16-inch wheels; the turbo, 17-inch) get the power to the ground very convincingly. A Torsen limited-slip differential splits torque between the rear wheels according to slippage. An optional electronic traction-control system can be manually selected by the driver.

Four-wheel antilock brakes are standard, as are dual air bags. Prices for the car, which goes on sale in June, have not been set. But the Supra won't be subject to the gas-guzzler tax: It gets a reasonable 18 mpg in the city and 23 mpg on the highway.

—Richard Stepler





Nissan's new air-bag system, available in 1993 on some Japan-only models, deploys behind the driver.

you've got a way to go; it remains silent until it warns that your exit is approaching. On local roads it announces turns when they are about 300 yards ahead and again when they are 30 yards ahead. It even handles multiple turns such as: "In about 30 yards, turn right. Then after 20 yards, turn right again." And, unlike some human navigators, it doesn't get angry if you miss a turn. It simply refigures your route at the press of a button.

The only problem I had was when the system didn't realize I was traveling on a highway stacked above a local street. Following the system's directions to turn would have sent me into the guardrail. A Toyota spokesman says there is a way to avoid that, but you have to read the fine print in the owner's manual to find out.

Toyota developed the system with Aisin A W Co., an affiliated parts maker, and claims it is the first voice-navigation system in a production car. Currently, it is available only as an option on Toyota's luxury Celsior model, the equivalent of the Lexus LS400 and available only in Japan. Toyota has no immediate plans to offer the system elsewhere, but that could change depending on demand.—Dennis Normile

Rear-seat air bag

Nissan expects to have a rear-seat air bag system on some Japan-only car models in 1993, which would make it the first company to offer such a system on a production car.

Rear-seat air-bag systems have not received the emphasis of the more popular driver-side or front-seat-passenger systems. Such systems do, however, offer protection for rear-seat riders as well as for passengers in the front seat who are subject to injury from unrestrained riders in the back of the car.

A rear-seat system is more complex than its front-seat equivalent now in use, according to Nissan. And with good reason: Rear-seat passengers tend to sit in a greater variety of positions, and children are more likely to be seated in the back.

The Nissan restraint is about 1.5 times greater in volume than the driver-side air bag and has a two-stage inflator that reduces inflation noise and moderates changes in bag pressure. Inflation is triggered by two impact sensors mounted in the floor tunnel of the passenger compartment. The rear-seat air bag restricts seat adjustment, and there is still concern about inflating numerous bags simultaneously in the confined space of the car interior. Currently, the plan is for a rear-seat bag only behind the driver's seat.

Fuel-cell alternative

Mazda is not the only company working on a fuel-cell-powered electric car. The company does claim, however, to be the first with a prototype based on a proton exchange membrane (PEM) fuel cell.

A PEM fuel cell uses a solid polymer electrolyte similar to those used in fuel cells for space applications. The membrane assembly is a sandwich, with the solid polymer electrolyte in the middle, a layer of platinum catalyst on each side of the membrane, and a cathode and anode of porous carbon, one on each side. As with other fuel cells, hydrogen or hydrogen-rich substances such as methanol and natural gas are used as fuel.

What makes the PEM fuel cell attractive for auto applications is its ability to provide power on demand. This differs from phosphoric-acid fuel cells that take

PREVIEW DRIVE

NEW FEATHERS FOR THE FIREBIRD



The 1993 Firebird is an impressive update on the pony-car theme. But even more striking is how it combines highway manners and track performance—about as well as some expensive German cars. The new Firebird rides more smoothly on the road than its predecessors, with a more rigid chassis and fewer rattles.

On the track, as proven at the model's Road Atlanta press introduction, the Firebird is a revelation. The premium models handle with confidence-inspiring precision, mainly due to their new short/long arm (SLA) front suspension (instead of last year's struts), plus deCarbon shock absorbers, new rack-and-pinion power steering, and, on the Formula and Trans Am, P245/50ZR16 Goodyear Eagle GS-C tires on 16-by-8-inch cast aluminum wheels.

The new Firebird comes with either a 160-

hp, 3.4-liter V6 or a 275-hp 5.7-liter LT1 V8. The base model's six provides economy with solid performance, while the light is impressive on the road and even more so on the track.

The V8, whose presence can be heard as well as felt from the driver's seat, is standard with the Formula and Trans Am, as is the new Borg-Warner T-56 six-speed transmission—slick shifting and with a ratio for every occasion. Only standard gear ratios differentiate the Formula and Trans Am mechanically, the Formula sharing the base Firebird's slightly less dramatic styling. An electronic four-speed automatic is optional across the board.

The new Firebird is even affordable, unlike those German marques: The base bird's list price is estimated at \$14,000 and the Trans Am is about \$21,500.—John Matras

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P R E V I E W D R I V E

NISSAN'S STYLISH ELECTRIC



The light weight of its all-aluminum frame keeps the all-up curb weight of Nissan's Future Electric Vehicle (FEV) slightly less than 2,000 pounds, which includes 444 pounds of quick-charging nickel-cadmium batteries.

The light weight is responsible for acceleration that, while not exactly tire-smoking, at least keeps up with traffic. A short drive in the FEV at Nissan's research and development center in Farmington, Mich., also demonstrated the attention paid to weight distribution and suspension. Handling was sporty, with the steering a bit stiff.

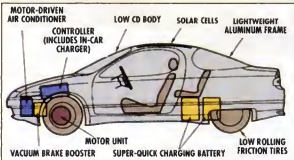
Nissan is ahead of other Japanese auto companies in developing electric cars mainly because it started in the mid-1970s. The company has since put a significant number in service.

The prototype FEV is both compact and stylish, with amenities that include a heat-pump air conditioner and air bags. The quick-charge system the Japanese automaker has developed to recharge the

battery pack—40 percent in six minutes—is one answer to the electric car's inherent short range.

A demonstration at Nissan's research and development center proved that the vehicle is relatively easy to hook up and operate. The quick-charge station itself operates on 440 volts, but such current is not widely available.

Even the research center did not have an adequate source of power for the quick-charge demonstration—current was supplied by a huge diesel generator running behind the research building.



Batteries in Nissan's FEV are installed behind the rear seat, with the quick-charge outlet at the rear.

time to reach full power and then run best at constant output. Mazda says a PEM fuel cell could provide stop-and-go power without the supplemental batteries required by phosphoric-acid fuel-cell-powered cars such as the Marai 1, unveiled by Sanyo last year ("Automotive Newsfront," Aug. '92).

But the technology has a way to go. Mazda's demonstration vehicle has a top speed of 25 mph and can only travel 7.5 miles on one charge of hydrogen fuel. The company is concentrating its research on boosting the power output, developing hydrogen storage and handling technology, and reducing costs.

Commercialization is far in the future.

The PEM fuel cell was provided by Ballard Power Systems of North Vancouver, B.C. According to the company, an electric bus fitted with its fuel cells will be tested in Vancouver beginning this spring. Daimler-Benz and General Motors are also evaluating Ballard's PEM fuel cells.—Dennis Normile

Volts jolt hot cat

An electrically heated catalyst with a metal rather than a ceramic substrate is now being evaluated as a way to meet the stringent 1997 California

emissions standards ["Automotive Newsfront," July '92].

Emitec, a joint venture between Siemens in Germany and Britain's GKN, claims clear advantages for the all-metal catalyst. For starters, since wall thickness of the metal substrate is a quarter that of a ceramic matrix, power-robbing back-pressure in the exhaust system is correspondingly lower for any given surface area. Hence the converter can be smaller and lighter, yet has great mechanical strength.

Metal also heats to operating temperature faster than ceramic, reducing cold-starting emissions during the critical warm-up period, and uses less battery energy to do so. The metal functions as the actual resistive heating element; ceramic must be coated with electrically conductive metallic powder to achieve the same effect.

The basic honeycomb matrix consists of alternate sheets of corrugated and flat 0.002-inch-thick steel alloy foil rolled into a cylindrical form. Two paired foils are wound around separate axes as interlocking S-shapes inside a tubular outer housing. Internal contact points of the foil are brazed to solidify the substrate and prevent telescoping under the pressure of the exhaust gases.

For electrical heating there's selective brazing plus added insulating material to provide a circuitous resistive path through the entire matrix. Current drain is approximately 300 amperes—comparable to a starter motor—but in bursts of just a few seconds under electronic control regulated by thermo-sensors. This inhibits the starter circuit so that you can't crank a cold engine until the catalyst temperature reaches 300°C. Then the alternator carries most of the heating load before the hot exhaust takes over.

Emitec's hot cat is undergoing reliability testing in Europe prior to production and is being tested in a special fleet of Volvos running in California. —David Scott

Automotive note

•Microscopic venetian blinds are encapsulated in a new plastic film developed by 3M. The microlouvered film has applications on automotive instrument panels, cutting glare while enabling the driver to see the instruments. Equally important may be its use on bank automated teller machines, where it prevents anyone standing alongside the machine from reading the screen. **MS**



4x4

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OUT OF THE BLACK

SECRET MACH 6 SPY PLANE

**An eyewitness description,
a secret test site, and a new
analysis of advanced aeronautics
paint a portrait of Aurora.**

BY BILL SWEETMAN

Does the U.S. Air Force—or perhaps one of America's intelligence agencies—have a new secret spy plane in action? A growing body of evidence suggests that the answer is yes. A startling disclosure came recently when Chris Gibson, a British oil engineer and highly trained aircraft-spotter, produced a sketch that captured the shape and size of an unusual aircraft he saw during daylight hours in August 1989, flying over his drilling rig in the North Sea. The expert eyewitness's drawing is the keystone that, with other evidence, provides an understanding of a secret hypersonic reconnaissance aircraft that is widely rumored to exist, but routinely denied by U.S. officials. Its nickname is Aurora.

Gibson—a former member of the disbanded Royal Ob-

server Corps, a group of volunteer aircraft-spotters—was able to estimate the strange airplane's length and width by comparing it with the known dimensions of the K-135 refueling tanker and two F-111 bombers flying alongside. But it wasn't until last year, when he came across a magazine illustration of a hypersonic (faster than Mach 5) aircraft design, that Gibson suddenly made sense of the sharp triangular silhouette he saw.

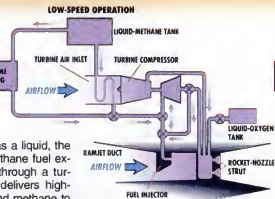
Analysts believe that Aurora is an operational spy plane that replaces the retired Lockheed SR-71 Blackbird. Like its predecessor, Aurora costs several million dollars per flight and is sent out only on missions where the plane's sensors can gather vital information unobtainable by satellite reconnaissance or other means.

It's plausible that Aurora was used to photograph Iraq

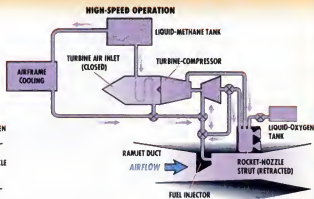


THE COMBINED-CYCLE RAMJET ENGINE

Unlike any single type of power plant, the combined-cycle engine can power an aircraft from a standstill to about Mach 6 (4,400 mph) by using elements of a ramjet and a rocket. Stored as a liquid, the engine's cryogenic methane fuel expands to a cold gas through a turbine-compressor that delivers high-pressure outside air and methane to rocket nozzles in the ramjet duct. At start-up, the mixture is ignited, causing a supercharging effect that draws more air through the duct. During idle, the low airflow rate in the large duct creates a cyclic buildup and release of pressure, producing the loud, low-pitched noises associated with Aurora. Adding liquid oxygen (LOX) to the rocket nozzles increases their exhaust velocity and draws more air through the ramjet, boosting thrust for take-off and acceleration. As ram-effect compression heating begins to occur in the tapered duct, a fuel injector adds more methane, which



combusts downstream of the rocket nozzles. Liquid methane cools the plane's airframe and engines as speed increases, densifying incoming air and adding energy to the turbopump, which augments rocket thrust. LOX flow is gradually reduced to zero at about Mach 2.5, as airflow into the ramjet increases. At higher speeds, the rockets are shut off and the nozzle strut retracted to reduce drag. Now fuel is delivered only through the injector, and the engine runs as a pure ramjet up to about Mach 6.—*Bill Sweetman*



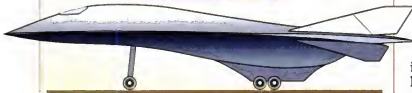
combusts downstream of the rocket nozzles. Liquid methane cools the plane's airframe and engines as speed increases, densifying incoming air and adding energy to the turbopump, which augments rocket thrust. LOX flow is gradually reduced to zero at about Mach 2.5, as airflow into the ramjet increases. At higher speeds, the rockets are shut off and the nozzle strut retracted to reduce drag. Now fuel is delivered only through the injector, and the engine runs as a pure ramjet up to about Mach 6.—*Bill Sweetman*

THREE VIEWS OF AURORA

REAR VIEW



FRONT VIEW



Huge exhaust nozzles (top) dominate Aurora's tail. Rectangular inlets (middle) feed air to the ramjet engines. The contoured underbody (bottom) compresses incoming air and expands exhaust to produce thrust.

IAN WORTHVILLE

during Operation Desert Storm in an attempt to provide tactical intelligence to ground-based military commanders. Aurora's unique capabilities also equip it for surveillance of nuclear proliferation. The list of nations of varying political complexions that covertly possess or are pursuing nuclear arms capabilities includes India, Iran, Iraq, Israel, North Korea, Pakistan, and South Africa. Surprise visits by a reconnaissance aircraft can give intelligence analysts clues—such as the presence of military trucks at an ostensibly civilian plant—which wouldn't be left out in the open when a spy satellite is scheduled to make its pass overhead.

Aurora overflights of Russia have probably not occurred. Such missions would violate an agreement in place since a Lockheed U-2 spy plane was shot down over the Soviet Union in 1960. It is likely, however, that Aurora monitors the submarine-building programs of Russia, China, and other nations from well outside their airspace using side-looking sensors.

Gibson's North Sea sighting completes a puzzle that has obsessed military-aircraft analysts for several years. Consider the following pieces of evidence hinting at the existence of something unacknowledged that flies high and fast:

- In February 1990, the Air Force retired its SR-71 spy planes. The official reason was saving the \$200 million to \$300 million a year it cost to operate the fleet of Blackbirds. Reporters were told that the SR-71's role had been taken over by advanced spy satellites.

TR-3A BLACK MANTA

Somewhat bigger and much quieter than the F-117A stealth attack plane, a stealthy reconnaissance aircraft identified as the TR-3A may already be in service, according to a report by the Federation of American Scientists. The subsonic, unarmed Black Manta's likely role would be to loiter unobserved as far as 100 miles from its target, taking pictures and conducting electronic eavesdropping. Its mission is similar to that of the U-2R, a version of the veteran spy plane still in use, but the Black Manta's targets would probably be unaware of its presence. A small fleet of Mantas (perhaps 20 to 30) may have been produced by Lockheed or Northrop.

MARC BRIDGON



The closely guarded Air Force test facility at Groom Lake in southern Nevada is shown in this 1992 photo, taken from a vantage point on public land about 14 miles to the east. Visible are a section of the six-mile runway and, at right, a complex of large, low buildings similar to the B-2 bomber plant in Palmdale, Calif. In front of them are hangars that once housed CIA A-12 spy planes. The secret base has doubled in size since it was photographed in 1978.



- The money saved was less than 7 percent of the approximately \$4 billion the Air Force spends yearly on satellite reconnaissance—mere chicken feed by Pentagon standards. Keeping the SR-71s in reserve would have provided cheap insurance against an unlucky string of satellite and rocket failures, such as the ones that occurred in 1985-'86.

- The Air Force actually discouraged congressional attempts to reverse this termination of its most glamorous aircraft mission. Never in its history had the flying service walked away from a manned mission without a fight.

- The pace of activity at the Air Force's top-secret Groom Lake test site in the Nevada desert has increased dramatically in recent years, suggesting the presence there of one or more secret aircraft programs. By comparing recent photos of the base with ones taken in the late 1970s, it's apparent that several large new buildings were added during the 1980s. Always visible in the recent pictures are a number of chartered Boeing 737 airliners that ferry workers in from other defense-industry towns such as Palmdale, Burbank, or Edwards in Southern California, or from Nellis Air Force Base in Nevada.

- Since mid-1991, unexplained sonic booms have periodically rattled Southern California. Officials at the United States Geological Survey, the agency that monitors earthquake activity, no doubt irked the military with their public statements that a very fast, high-flying aircraft was causing the "airquakes" (see diagram, page 60) registering on their array of seismographs.

- The Federation of American Scientists, a private Washington, D.C.-based policy group, issued a report late last year on the likelihood that unacknowledged military aircraft might exist (see Flying in the Government's Black World). The cautious review of unclassified literature on the subject concluded that several new types of aircraft may indeed be covertly flying around.

It is close to midnight, but all the clocks are set to 0730 Greenwich time. In a closed and guarded hangar, ground crews help two men in orange pressure suits clamber into a delta-shaped, dull black airplane.

MOTHER SHIP

Observers in California's Mojave Desert have reported sighting a large aircraft resembling both the SR-71 and the XB-70, a 1960's Mach 3 bomber prototype. A flat area atop the plane's aft fuselage appears to serve as a mounting point for an unknown object—hence its nickname, "The Mother Ship." Piggyback payloads could include an air-launched satellite delivery vehicle, an antisatellite weapon, or a high-speed aircraft lacking a low-speed propulsion system. A vehicle of this kind could operate discreetly from inland sites, and fly to overwater areas before accelerating to maximum speed and launching its upper stages into orbit or ultra-high-altitude flight. Engineers familiar with aircraft structure, aerodynamics, and stealth design assisted in developing the drawing.

The pilot touches keys that tell computers to start the engines. At first, the aircraft emits a subdued whine, which builds up quickly and is joined by the sound of rushing air. Then there is a flash of light from the intake and exhaust ducts as a wave of noise explodes, rolling harshly across the dry lake bed. Within the roar are the scream of small rockets, the crackling thunder of a huge fighter engine, and a massive pulsing—as low as one cycle per second—that shakes the entire desert base.

Gibson's sighting now makes it possible to reconstruct the Aurora program's history. The spy plane was operational, or nearly so, by August 1989, just before the Air Force parked its SR-71s for the last time. Aurora would have made its first flight by 1986 at the latest, following a development effort that was launched in 1981.

This analysis elicited denials by high officials involved in defense and intelligence matters. Ohio Democratic Sen. John Glenn asserted that his sources in the intelligence community told him there was no such aircraft. "I think they're telling the truth," he said.

Pete Williams, chief spokesman for the Bush administra-

tion's Secretary of Defense, Dick Cheney, gave a standard answer to a query about Aurora. "If there were such a program, we wouldn't discuss it." Williams explained that Pentagon policy says the same answer "must always be given" to queries about secret programs—whether or not they actually exist—to avoid revealing the truth. Donald B. Rice, Bush's Secretary of the Air Force, stated: "There's no program in the Air Force, none anywhere else that I know of. It simply doesn't exist." To some observers the stridency of Rice's response was puzzling. Why didn't he simply utter the usual Pentagon disclaimer?

Black is the adjective most often applied to the hidden world in which such engineering activities unfold. In a 1985 Pentagon budget document requesting production funds for 1987, a censor's slip let the line item "Aurora" appear, grouped with the SR-71 and U-2 programs. Even if Aurora actually was the project's name at the time, it almost certainly would have been changed after being thus compromised; "Senior Citizen" is one new label that has been reported. Rated by the Pentagon as an "unacknowledged special-access program," the plane's existence and real name are secret, and therefore deniable.

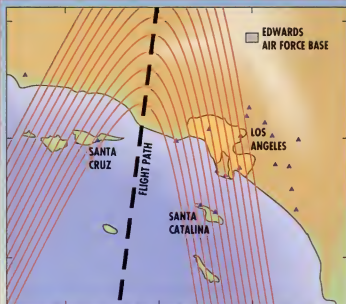
Unconfirmed reports of Aurora's existence first surfaced in 1986, and *POPULAR SCIENCE* conjectured about the airplane's likely design in the November 1988 issue. Now, fresh reports from secret-airplane hunters like James Goodall, who heard and felt bone-shaking sounds coming from the Groom Lake facility late in December, continue to flesh out the picture of Aurora and the technology that makes it work.

Armed with patience and braced for the occasional confrontation with no-nonsense security patrols, resolute observers like Goodall trek through the harsh Nevada desert to a mountainside overlooking desiccated Groom Lake. From several miles away—as close as they can get without entering off-limits government land—the watchers can see the large air base with its motley collection of hangars. Some of the buildings are vast.

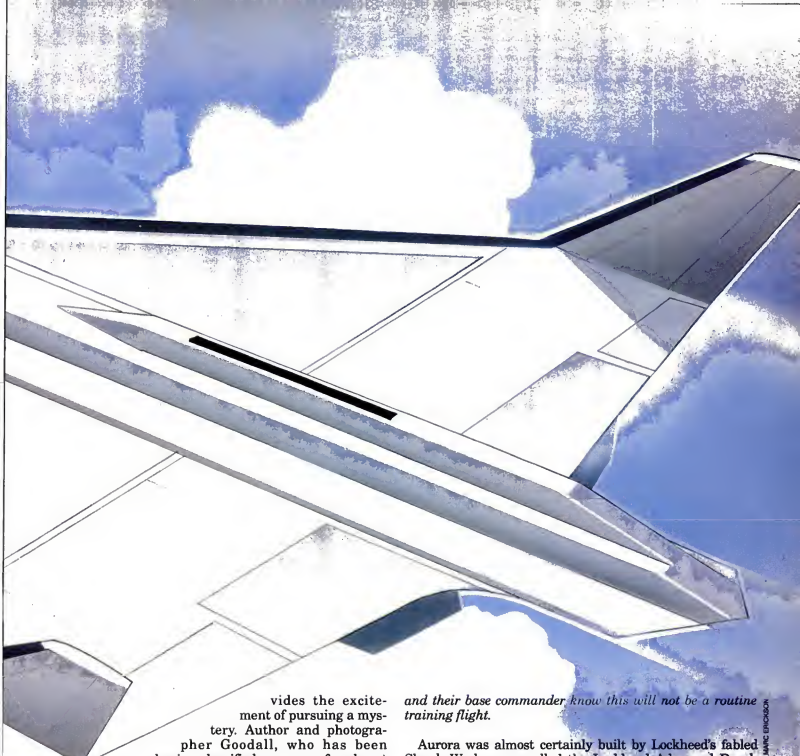
Yet, like a mirage, the isolated facility with its six-mile runway doesn't exist—officially, that is. And its non-existence is longstanding. A 1992 Lockheed Corp. paper on the early days of the U-2 program refers to flight-testing at Groom Lake 35 years ago as having occurred merely at "a remote location."

For some, monitoring events on the dry lake bed pro-

AURORA'S FLIGHT PATH



An unidentified aircraft traveling across Southern California at Mach 3.1 on Jan. 30, 1992, jiggled U.S. Geological Survey seismographs with its sonic boom, different from that produced by the SR-71 or the space shuttle. The craft's boom "footprint" traces its flight path toward southern Nevada.



vides the excitement of pursuing a mystery. Author and photographer Goodall, who has been chasing classified programs for almost 30 years, is motivated by enthusiasm for aircraft and a conviction that he's entitled to know how his taxes are being spent. His earwitness account indicates that the airplane's propulsion system is unconventional, to say the least. "We heard Aurora from 18 miles away. The sound is so intense that you feel it. It was quite something else—a pulsing noise that you'll never forget."

The airplane begins rolling forward at half-past midnight, then accelerates and noses up into the sky like a hot fighter. Seconds later it is gone, trailing a shattering roar across the desert. In the cockpit, the pilot sees his course overlaid on a detailed map as the craft climbs through 60,000 feet at a steep 70-degree angle. Just minutes after takeoff, the plane is cruising northeast at six times the speed of sound, covering almost one mile per second. More than 20 miles above the ground, it passes unheard over Montana and North Dakota into Canadian airspace.

Five thousand miles away, a loaded KC-135 tanker lifts heavily into the early morning sky from a secure air base in western Scotland. At a second base farther south, four F-111 crewmen walk toward their pair of aircraft. Only the crew

and their base commander know this will not be a routine training flight.

Aurora was almost certainly built by Lockheed's fabled Skunk Works, now called the Lockheed Advanced Development Co. Of all known design organizations, only the Skunk Works has the proven ability to manage large programs incorporating breakthrough technology in total secrecy. Analysis of Lockheed's financial statements makes it possible to estimate Aurora's price tag at about \$1 billion per aircraft. At most, 10 to 20 of the new spy planes have been built.

A hypersonic prototype paved the way for Aurora. In 1975, Lockheed proposed a small hypersonic research aircraft that would be launched from the back of an early version of the SR-71. And a definitive survey of Lockheed aircraft, published in 1982, stated that the company had already flown a Mach 6 experimental craft.

By the late 1970s the U.S. government probably had two main reasons for going ahead with Aurora. The first: improved Soviet surface-to-air missile (SAM) systems posed an increasing threat to the SR-71, which flies at Mach 3.2 (2,100 mph) and reaches altitudes above 80,000 feet. By 1980, two potent new Soviet anti-aircraft weapons, the SA-10 Grumble and the SA-12 Gladiator/Giant, were under development. Both have a maximum altitude of about 100,000 feet and feature advanced tracking and guidance systems.

FLYING IN THE GOVERNMENT'S BLACK WORLD

The Pentagon's "black world" isn't a mirror-military running parallel to the familiar one. Rather, it is a submerged network of covert activities distributed throughout the armed services and other agencies. Its size can be gauged from unclassified Pentagon budget documents, which include accurate total figures but conceal individual black programs by labeling them with code names or burying them within other categories.

This hidden ocean of funds for research, development, and production of secret equipment amounts to \$16 billion of the Pentagon's \$254 billion 1993 budget. When operations costs are included, the black budget's estimated annual total comes to a staggering \$35 billion.

New construction at the Air Force's secret Groom Lake test facility in Nevada, and the number of workers being flown to and from there in recent years, suggest that a decent chunk of this invisible money is being directed toward several unacknowledged, large-scale aircraft or missile projects under way at the remote site.

The Air Force has hidden major aircraft programs before on two occasions. A giant Lockheed airplane called the CL-400 was the U-2 spy plane's intended replacement. Code-named Suntan, the Mach 2.5 aircraft was to be powered by radical hydrogen-fueled engines.

Lockheed had virtually completed the first four aircraft before Suntan was canceled in 1958 due to technical snags. The project cost \$250 million in fat 1950's dollars. Not one word leaked out about Suntan until 20 years later, when Lockheed started talking about liquid hydrogen as a future aircraft fuel.

Suntan was replaced by a CIA project for a Mach 3 spy plane called Oxcart. After Lockheed was selected to build the plane, it was renamed the A-12. It first flew in April 1962 from Groom Lake, which was made into a fully equipped base supporting A-12 flight testing and the CIA's dozen operational planes.

The Air Force subsequently ordered 30 SR-71 reconnaissance-strike aircraft derived from the A-12 prototype. The existence of the SR-71 was disclosed in a 1964 statement by President Lyndon Johnson. But the CIA's A-12s flew secretly until mid-1968, and they were not revealed to the public until 1982. Through a combination of tight security and disinformation, the A-12 program was concealed for 23 years. Now ask yourself: Would your government lie to you?

In "Mystery Aircraft," a report released last year, the Washington, D.C.-based Federation of American Scientists (FAS) concluded that two or more types of secret airplanes are likely to exist. Based on an extensive analysis of unclassified Pentagon and corporate financial documents, technical papers, and a range of news reports, the study favors the view that some of the reported aircraft are prototypes, while at least one may be in regular service.

"It is probable that at least one high-speed, high-altitude experimental air vehicle is currently undergoing flight tests," or may possibly have achieved operational status, the report states. The craft could be manned or unmanned, it notes, fitting either the general description of a Mach-4 to Mach-6 Aurora or a faster Mach-8 "exotic propulsion aircraft" using pulse-detonation or external-combustion technology to reach hypersonic cruise speed.

The "doughnuts on a rope" exhaust contrail ("Science Newsfront," Aug. '92) photographed last year in Texas might be the product of a pulse-detonation type of engine, which combusts its fuel in intermittent bursts. An aircraft using external combustion at high speeds would fit the description of a vehicle dubbed "The Pumpkin Seed" (see drawing).

According to the FAS study, "There is also the possibility that the SR-71 follow-on is

hidden in plain sight" within the National Aerospace Plane (NASP—also known as the X-30) project, which is aimed at developing an air-breathing hypersonic craft that can climb into low-Earth orbit from a runway in a single stage. Knowledge about propulsion and high-temperature structures gained in the NASP program may have proven applicable to a Mach 6 to Mach 8 aircraft now flying.

As many as a few dozen examples of a subsonic stealthy reconnaissance aircraft called the TR-3A or "Black Manta," probably built by Lockheed, may currently be in production or operational, the FAS analysts say.

Finally, it is highly probable that some one- or two-of-a-kind stealth aircraft prototypes exist, the study concludes. Such aircraft would be built to test concepts intended for the B-2 bomber, the TR-3A, the Navy's canceled A-12 stealth attack plane (no relation to the SR-71's predecessor), or other aircraft. These planes could account for the number of different mysterious aircraft described in sighting reports.

Putting aside the romance of sifting clues about secret airplanes possessing wondrous characteristics, the authors of the FAS report raise a broader fundamental question: With the Cold War behind us, what's the effect of continuing to support such vast and costly secret defense activities?

The hard-nosed answer is provocative: "Secrecy tends to obstruct technological development by inhibiting communication of useful information, increasing costs, generating public mistrust, and all too often promoting fraud and abuse," the study says. "It is being used to protect controversial programs from public awareness, more than from hostile intelligence services."

Recent major examples of secrecy masking incompetence include the B-2 stealth bomber program, which has been shot through with cost overruns and performance shortcomings, and the disgraced Navy A-12 program, which was killed after billions of dollars of misguided expenditures.

The sentiment expressed by FAS is gathering broad support in Congress and elsewhere. Its message to the Pentagon is this: Unjustified secrecy is anti-democratic. —Bill Sweetman and Stuart F. Brown

Black, fast, and retired. The military insists there's no successor to the SR-71.

The second reason for building Aurora was that satellites alone are not the best solution to reconnaissance requirements. While they take superb pictures, satellites also have inherent limitations. They follow fixed, predictable orbits, which make their appearance no surprise to a shrewd adversary. Although earthbound controllers can command satellites to fire thrusters to adjust their orbits, this ability is strictly limited by a finite on-board fuel supply. In addition, because it is difficult to supply the amount of power needed to operate an all-weather radar, most satellites carry only daylight or low-light cameras.

Although they cost several hundred million dollars apiece, spy satellites last, on average, only five years before they are dumped into the atmosphere and replaced. And it is difficult to increase surveillance quickly in a

crisis unless a stockpile of reserve satellites and launchers is kept ready—as the former Soviet Union once did.

Aircraft are much more flexible. They can be dispatched exactly where and when they are needed, and they can be fitted with day, night, or bad-weather sensors, depending on conditions in the target area.

During the hour it takes to reach the initial point for descent, the pilot and reconnaissance systems officer (RSO) in the backseat are fully occupied with checking equipment to see how it operates in the 1,000°F friction heat soaking into their aircraft's structure. On the way down, the flight profile is computer-controlled—a delicate balance between speed, altitude, and deceleration rate.

Over the North Sea, the tanker and the F-111s gather into

a loose formation and follow a racetrack pattern. Appearing suddenly, the black jet turns in behind the KC-135 and connects with its refueling boom, wavering a little while matching the tanker's low speed. During the next ten minutes, 40 tons of liquid methane flow into the spy plane before it turns away and hurtles skyward. Already, another loaded methane tanker and two more F-111s are preparing to depart their bases in Britain.

An analysis of Aurora's three-dimensional shape can be extrapolated from its 75-degree swept triangular outline. The aircraft corresponds almost exactly in form and size to hypersonic reconnaissance aircraft studied in the 1970s and 1980s by McDonnell Douglas, according to Paul Czyst, now a professor of aerospace engineering at St. Louis University.

Czyst worked on hypersonics while at McDonnell Douglas, including the company's proposal for the National Aerospace Plane program ["X-30: Out of This World in a Scramjet," Nov. '91], and is an acknowledged expert in the field. Efficient hypersonic planes "are basically air-breathing propulsion systems," he says.

Like the SR-71, Aurora has a crew of two. Flying it is quite unlike piloting a conventional aircraft. There is little if any outside view, because a normally angled windshield causes too much drag and gets too hot. For these reasons, Aurora may have a retractable windshield used only for takeoffs and landings; at other times, the windshield would be covered by a heat shield.

Aurora's pilot is really a mission manager, monitoring the

aircraft and its systems and following the course of the flight on large-format video displays. His or her most important function is to cope with the unexpected: shifts in upper-atmospheric temperature, weather developments over the target area or refueling zone, or problems with the plane's mechanical or electronic systems.

The RSO supervises a battery of sensors. The most important is a synthetic-aperture radar (SAR), a side-looking instrument that takes a sequence of snapshots of the target as the aircraft moves and compiles them into a single radar image that is as sharp as if it had been acquired using an antenna hundreds of feet wide. The best SAR images are classified, but have been described as "near-photographic," allowing different types of land vehicles to be easily distinguished from more than 100 miles away, regardless of clouds or smoke.

In clear weather, Aurora uses daylight and infrared cameras for ultra-detailed work. And unlike a satellite, the craft can be scheduled to make its reconnaissance passes at the golden hour for covert imaging: early morning, when the low sun provides even illumination and long shadows that highlight features on the ground, before heat-induced haze forms.

A phased-array antenna built into Aurora's upper surface—near the tail end, where aerodynamic heating is minimal—allows the airplane to transmit real-time or near-real-time imagery to the Pentagon's satellite network.

In a Middle Eastern country, a bored radar operator in an underground shelter fails to notice a faint blip on one edge of his screen. The system's computer can't make sense of

(Continued on page 98)

PUMPKIN SEED

Reports of a brightly glowing aircraft moving very rapidly across the night desert sky at high altitudes may be attributed to the use of external combustion. The exotic hypersonic propulsion method involves igniting fuel released from ports girdling the plane's flattened, diamond-shaped body. Exhaust expands in the conical area defined by its shock wave to produce thrust. Turbojets provide propulsion at low speeds. Here, an exotic propulsion demonstrator is seen as it transitions from a turbojet-type accelerator to external-burning power. In theory, control at high speeds could be provided by modulating the fuel flow to the propelling nozzles. This aircraft may be unpiloted.



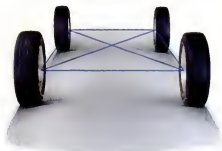
Beauty is only skin deep. Great engineering, however, goes all the way to the pavement.

CHEVROLET LUMINA EURO SEDAN

Admiring the Lumina's clean, angular shape doesn't make you a shallow person. But to discover its real beauty, we'd suggest a more thorough investigation.

Start at the bottom.

Developing the Lumina's 4-wheel independent suspension package was a



real trip: 100,000 miles' worth, to be exact. Along the way, more than 150 different suspension setups were evaluated.

It's no coincidence that the one we finally selected is the one that lets you make the most of Lumina Euro's smooth yet powerful 3.1 Liter V6 engine.

Rigid unibody construction means your senses will be stirred, not shaken.

The road of life is strewn with potholes. (Not to men-



tion bad patch jobs and crumbling asphalt.) Fortunately, the engineers who designed Lumina took this into account. Its stiff steel unibody works in tandem with the suspension to reduce body flex, for handling that's precise and predictable no matter how



inhospitable the pavement beneath you may turn.

All the conveniences of home. And nearly as much room.

A comfortable place to sit. Plush carpet underfoot. Good music on the stereo.

A place for your coffee mug. And plenty of room to spread out. And why not invite a few close friends to join you?

After all, Lumina has more interior space than Accord,



Camry or even Taurus. So let the Lumina's good looks turn your head. However, be forewarned: this is one automobile that's engineered for a long lasting relationship. Then again, what else would you expect from the Heartbeat of America?



**THE HEARTBEAT
OF AMERICA™**

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A HOUSE FOR ALL

It saves energy and the environment, has state-of-the-art electronics, facilities for the handicapped, and more.

BY MICHAEL MORRIS

Picture a home where your kids don't argue about having to do homework, but instead complain about not being allowed to spend more time on it; where, at the touch of a button, they can view and access as much information as at the local library; where the family room is also a media center that's able to share its audio and video throughout the house—and where your hand-held remote control can adjust not only the

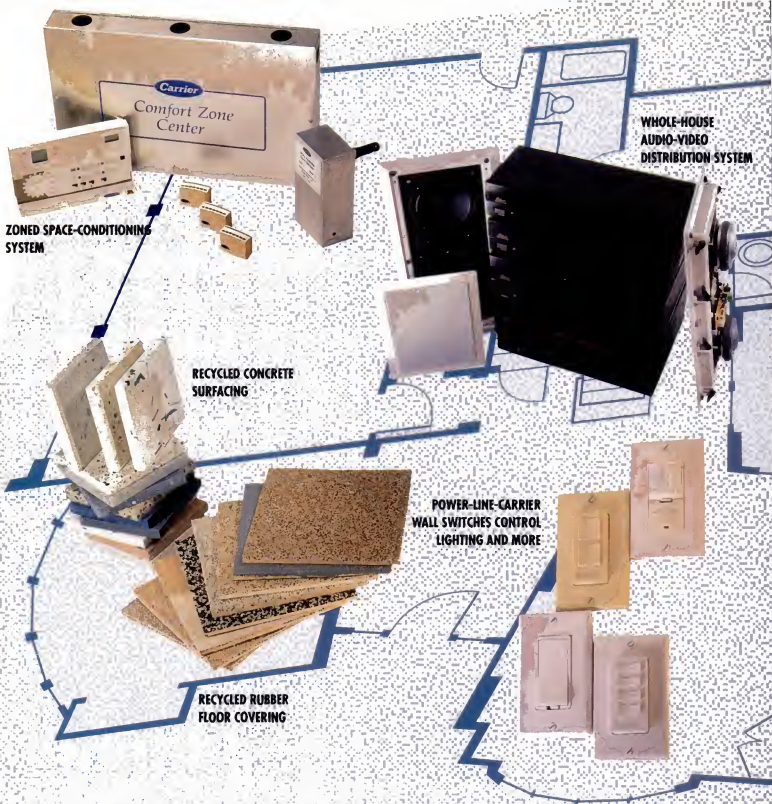
PHOTOS BY JOHN B. CARNETT



The serene Mediterranean styling of this compact villa houses some of the most technologically advanced home-building products available today.

REASONS





TV and stereo, but also the lights, heating and cooling, door locks, and even window shades.

Now picture that the home is built with recycled materials, and that it conserves heat and air-conditioning so its energy costs are reduced to an absolute minimum. Picture that it lets you program or reprogram every functioning part of it anytime you want—from your favorite chair or on a phone away from home.

Is this the "dream home" we have been awaiting for so long? Is this what our accumulated technology and manufacturing progress to date can do for

residential construction? If the answer is yes, then it must be the New American Home for 1993, cosponsored by POPULAR SCIENCE.

The home, a showcase of the latest and greatest home-related products, materials, methods, trends, and designs—and a barometer of sorts for current homeowner lifestyles in this country—opened its doors in February for the annual convention of the National Association of Home Builders in Las Vegas.

The judicious use of natural resources was a major theme in this year's home; advanced electronics in

home-automation and entertainment systems was another. But the overall goal was to incorporate these themes into a home designed for family living. This included finding ways to meet the special needs many families have, such as in this home's handicapped-accessible ground-floor bedroom suite (see Accessibility in the Bath).

Reducing the home's impact on the environment was perhaps the easiest to achieve, given the ever-increasing supply of available products. Leah Bryant, vice president and regional manager for builder

ACCESSIBILITY IN THE BATH

In the spirit of the 1990 Americans with Disabilities Act, this year's New American Home includes a ground-floor bedroom and bath suite designed to meet the needs of a handicapped resident. Although private homes do not have to conform to the provisions of the act, such a suite could be used for aging family members or a disabled child.

Passageways wide enough for wheelchairs or walkers and lever door handles are fine for bedrooms, but creating bathrooms suitable for special needs is more difficult—or has been, until now. To meet the demand for appliances and fixtures for the disabled, manufacturers have introduced products that conform to requirements of the act and the American National Standards Institute. Many of these offer features and styling that will appeal to nonhandicapped homeowners as well.



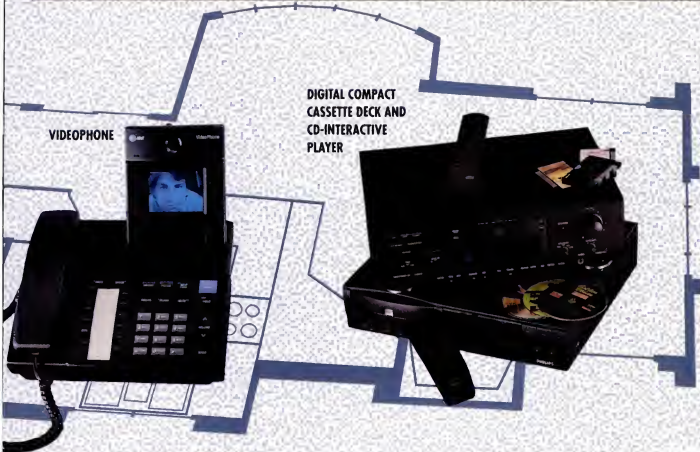
A door enables easy access to the bathtub.



The sink juts out for wheelchair users.

In the suite, the Kohler accessible bath fixtures include a high-pedestal toilet for easier seating and rising, a sink that extends forward of the counter and has an offset drain to allow wheelchair access beneath it, and a bath-whirlpool tub with a watertight side door

for easy entry. A folding seat for bathing or showering is built into the tub. The toilet's siphon-jet flushing system consumes just 1.5 gallons of water with each use. Scald-proof pressure-balancing faucets add to the room's safety features.—M. M.



VIDEOPHONE

DIGITAL COMPACT CASSETTE DECK AND CD-INTERACTIVE PLAYER

Lewis Homes of Nevada, adds that because buyers today are concerned with such issues as recycling and air and water quality, conservation is also a good selling point. "We do feel a need to put more products into our homes that are environmentally compatible," she says.

Many of the basic building components use innovative recycled materials. All of the home's wall studs, for example, are engineered 2x4s made from short lengths of wood that would formerly have been discarded as scrap. These pieces are reconstituted—finger-jointed and glued together—to create

studs that are as structurally strong as common lumber, and in some ways superior. Typically, construction lumber contains defects, and wood in its natural state is prone to splitting or warping. Makers of engineered lumber have eliminated most defects.

Steve Winn, project superintendent for Lewis Homes, was impressed with the wood's performance. "We typically send our best carpenter back into a house before the drywall goes up to straighten out any framing or replace bent or warped studs where necessary," explains Winn. "This usually takes about two days, but these studs

were so straight our guy was out of the house in just a couple of hours."

Louisiana-Pacific Corp., which manufactures the engineered studs, also provided the Nature Guard insulation in the home. The company claims this blown-in cellulose product, made of nontoxic flame-retardant-treated waste newsprint, offers the maximum resistance to heat loss among all loose-fill insulation products, with an R-value of 3.8 per inch.

To increase the effectiveness of the insulation, the house was enclosed with Thermax Blackore sheathing from Celotex. This foil-faced fiber-re-

DRAWINGS BY MARK PERRO



inforced board contains carbon black, a material that reduces heat transfer through the board's polyisocyanurate foam core. With an R-value of 6.5 at its $\frac{3}{4}$ -inch thickness, Thermax Blackore claims the highest rating of any insulated sheathing product. The home's Cor-A-Vent ridge vent is the first designed for the barrel-tile roofs prevalent in the Southwest.

Energy-conservation measures extend to the choice of exterior doors and windows. To defend against the

extremely hot southern Nevada sunlight, all of the Andersen windows and hinged and gliding patio doors were installed with argon-filled double-pane High-Performance Sun Glass. An improved metallic-oxide coating between the panes offers superior resistance to reflected sunlight. The low-emissivity glazing also helps retain interior heat during cold weather. Nassau Bahama Sunshades installed around the house also cut down the sunlight reaching the windows. These

adjustable aluminum louvers from Folding Shutter Corp. shade the glass when the sun is high, but don't impede light, ventilation, or view.

To complete the home's envelope, the exterior doors—including Pease Industries' Ever-Strait entry doors and Stanley Autograph garage doors—are all steel insulated with foam. The garage doors also have automatic openers with noncontact-reversing safety protection, now required by building codes nationwide; the closing

SOUND EFFECTIVENESS

COMPUTER WITH CD-ROM



The family room serves as Media Central in the 1993 New American Home, thanks to an Elan HD audio-video distribution wiring network. With this system, sound and television signals, including laser disc or recorded video, can be routed to any room in the house. Infrared repeaters in other rooms enable residents to control the system using hand-held remotes. This entertainment center, by Philips Consumer Electronics through Sears Contract Sales, includes: a 46-inch Wallvision2 rear-projection TV, a CD-I player incorporating Kodak-CD technology for television viewing of photographs and slides, a laser-disc video and hi-fi VCR, a dual-cassette deck, a five-



The home media center has a 46-inch TV.

disc CD changer, and the latest in audiotech: a digital compact cassette (DCC) deck. Unlike a compact disc, DCC allows for digital recording from any audio source. —M. M.

RECYCLED-NEWSPRINT INSULATION

HARDWOOD VENEER MOLDINGS

LUMBER FROM FINGER-JOINTED PIECES



doors will reverse if a person or object is standing in the path of its infrared beam.

Innovation and environmental concerns extend to the interior of the home as well. Syndcrete, a limestone-like material that incorporates up to 40 percent industrial and consumer waste, is used for the fireplace hearth in the living room. This product mixes cement, carpet fibers, and fly ash with aggregates of virtually any inert substance—from shredded plastic toys to

brass hardware shavings—to create solid blocks or slabs of near-limitless colors and designs.

Recycled rubber from automobile tires and other sources is the base for another new material, FlexTech, used on the home's outdoor decks. The resilient water-resistant covering from Bomanite Corp. is made from finely chopped rubber granules and resins that are mixed on-site and troweled in place by local contractors.

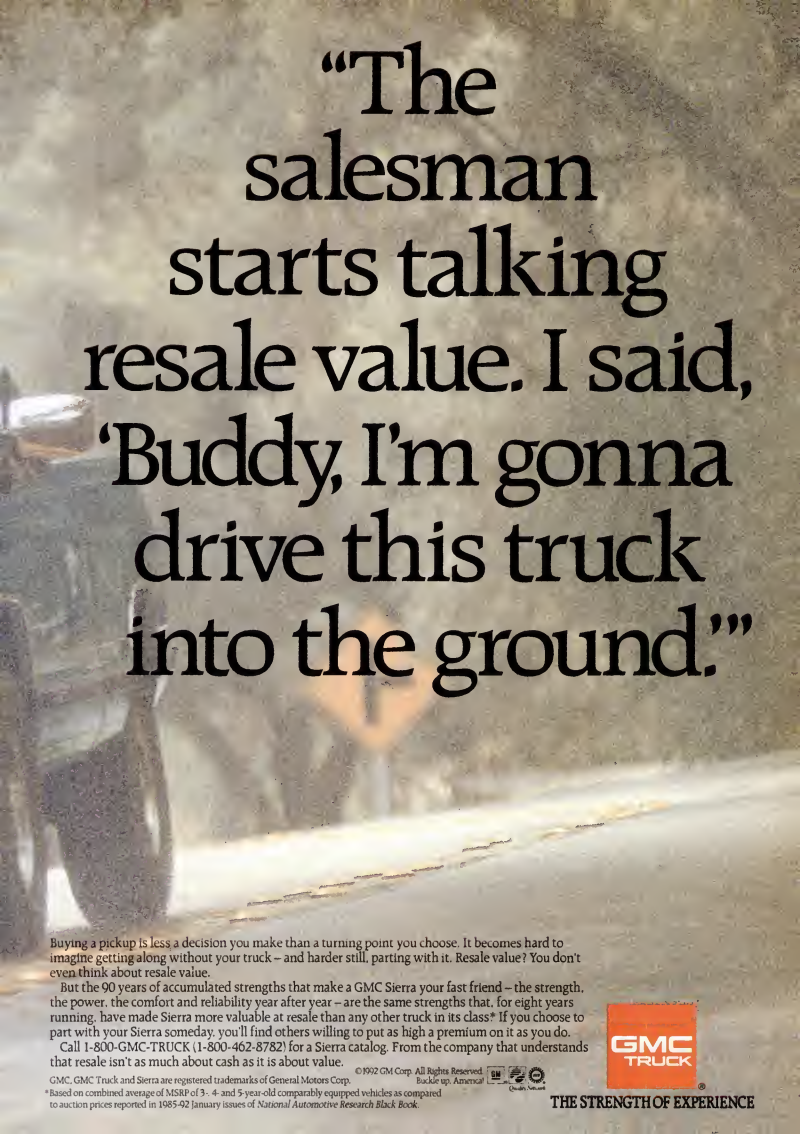
In some cases, cost helped deter-

mine the choice of materials. The Oak-Over moldings from Contact that were used throughout the interior, for example, have hardwood veneers laminated over a base of common softwood. These moldings look like solid oak but cost less and perform better than the real thing—they don't split when nailed, are consistent in size and shape, and are available in longer lengths.

Other items in the home that help

[Continued from page 102]





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resale value. I said,
‘Buddy, I’m gonna
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into the ground.’”

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*Based on combined average of MSRP of 3-, 4- and 5-year-old comparably equipped vehicles as compared to auction prices reported in 1985-92 January issues of *National Automotive Research Black Book*.



THE STRENGTH OF EXPERIENCE

Before human beings took to space, everyone worried about weightlessness. What would happen to the body—and to the psyche—without the comforting force of gravity? Would that dropping-elevator sensation, stretched over days or weeks, cause perpetual panic?

Well, it didn't. Weightlessness, space crews found, was bothersome, but you got used to it. Those who suffered from space motion-sickness—two-thirds of astronauts typically do on their first flight—simply lived with the nausea.

But now that the United States is committed to building space station

Freedom and to landing men and women on Mars, planners are beginning to worry again. The human body, it now appears, adapts only too quickly to microgravity—the extremely weak gravity experienced aboard spacecraft. (Astronauts don't actually experience zero-g.)

Scientists are concerned about what kind of shape astronauts will be in when they step out of their space capsule after a long trip to Mars, not to mention what will happen when they return to Earth. "Nobody has the foggiest idea of the effect of [microgravity] for extended periods," says Joe Sharp, director of research at

Astronaut Linda M. Godwin balances fellow crew member Jerry L. Ross on her finger during a flight of the space shuttle *Atlantis*.

A large photograph of astronaut Linda M. Godwin in a blue flight suit, smiling and balancing fellow crew member Jerry L. Ross on her finger. Jerry is a small figure in a white t-shirt, looking up at Linda. The background is white.

The Unbearable Lightness

NASA's Ames Research Laboratory at Moffett Field, Calif. And if astronauts go to Mars without that knowledge? "We may kill a few on the way, and we may get some wet noodles back."


During 30 years of spaceflight, American astro-

nauts have logged more than 50,000 hours in space. Yet, until recently, NASA devoted only a tiny fraction of its budget to studying microgravity's biological effects. "Significant unanswered questions exist," said a National Research Council report issued in 1990. "It has not been demonstrated that, after long-duration space flight, individuals can readjust rapidly to gravity without serious physiological consequences."

Yet NASA is forging ahead with plans to send astronauts to a \$30 billion space station for six months at a time; construction will begin in the late '90s. And in the early 21st century, NASA expects to send astronauts to Mars—a trip that will take a minimum of eight months each way. Americans have never before spent that amount of time in space; the longest stay is a Skylab mission that began in 1973 and lasted 84 days.

Russian cosmonauts have stayed up for longer periods. Sergei Krikalev, the cosmonaut trapped in space last year by the political and economic upheaval in his country, spent 313 days in the Mir

PHOTOS COURTESY OF NASA

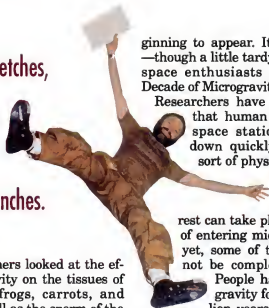


**Prolonged
weightlessness may
endanger human
health—and NASA's
plans for long
missions.**

BY ROBERT GANNON

of Space Travel

Without gravity, the spine temporarily stretches, causing backaches. Many astronauts come home from space missions taller than they left—gaining as much as 2.76 inches.



ginning to appear. It's a fitting start—though a little tardy—for what some space enthusiasts are calling the Decade of Microgravity.

Researchers have already learned that human bodies, like the space station itself, break down quickly in space. The sort of physical deterioration that, on Earth, occurs after months of bed

rest can take place within hours of entering microgravity. Worse yet, some of the changes may not be completely reversible.

People have depended on gravity for a couple of million years, and if you take it away, dire things can happen. Here are some of the most serious:

- **Muscle-Wasting.** In microgravity, muscles atrophy. During the nine-day SLS-1 mission in 1991, both humans and rats lost about 25 percent of the mass of major weight-bearing muscles, such as the thighs and calves. Only half of the lost muscle mass returned in the nine days after the astronauts landed. "This experiment has verified that muscles that support the body when we walk around on Earth change their nature in space because they are not needed," says Dr. Kenneth M. Baldwin, an exercise and muscle physiologist from the College of Medicine at the University of California at Irvine.

Exercise helps, but not much; astronauts who exercise vigorously in space still lose 10 to 15 percent of their strength over three months. Says space physiologist Danny Riley of the Medical College of Wisconsin: "Either it isn't the right type of exercise, or there's some pathology that causes muscle shrinkage and weakness that we don't know about."

- **Bone Brittleness.** In studies on rats, bones break more easily during spaceflight and take longer to heal. The reason: demineralization, or calcium loss.

A human being in microgravity doesn't need huge leg bones for support, so the body responds by discarding calcium at the rate of 0.3 to 0.4 percent a month. Heel-bone loss is more severe, about 5 percent a month. "On Earth, we call this osteoporosis," NASA administrator Daniel S. Goldin said in remarks before the National Space Club last year.

Eventually the bone loss reaches a state in which too little foundation bone remains to form a matrix for new bone to build upon. Some scientists view reduced bone density as the major medical deterrent to long-term spaceflight. They remain haunted by

space station. But he failed to break a world's record set by two fellow cosmonauts, who blasted off in 1987 and returned 366 days later. Yet, like the Americans, the Russians know surprisingly little about microgravity.

In the past year or two, however, the life-science database for space, sparse for so long, has begun to build. Astronauts on the first Spacelab Life Sciences mission (SLS-1) spent nine days performing experiments on each other in June 1991. Microgravity research last year got off to a walloping start with the January 1992 flight of the first International Microgravity Laboratory (IML-1). It carried scores of experiments, representing the work of some 200 scientists from 16 countries.

Projects aboard IML-1 involved everything from finding out the best way to make an astronaut sick (using a spinning, computer-controlled chair while tracking eye movements) to comparing the growth of tiny oat plants in microgravity and in an on-board centrifuge (data essential for space agri-

culture). Researchers looked at the effects of microgravity on the tissues of humans, mice, frogs, carrots, and slime mold, as well as the sperm of the African clawed frog. And they observed the reaction of the inner ear when its blindfolded owner, strapped to a sliding mini-sled, had electric shocks applied to the leg by a colleague.

Last summer, the United States launched another microgravity laboratory during the longest shuttle mission to date—14 days. Astronauts aboard the first U.S. Microgravity Laboratory (USML-1) conducted medical experiments, grew crystals, and studied the behavior of weightless fluids.

And in September, Japanese life-science microgravity experiments took flight on Spacelab J. This mission's crew studied the gravity-sensing organs of koi fish, measured muscle and bone loss with magnetic resonance imaging, and used biofeedback to ward off motion sickness.

Results from these missions are be-



Mission specialists N. Jon Davis (left) and Mae C. Jemison prepare to deploy on inflatable device that seals around astronaut's waist, drawing blood and other fluids to the lower body.

those photos of long-flying Soviet cosmonauts carried from spacecraft on stretchers, their bones and muscles too weak to hold them upright.

A class of drugs used experimentally to treat osteoporosis may help solve the problem. Scientists at Ohio State University have demonstrated that one of these drugs, called aminohydroxybutane biphosphate, can prevent bone loss in rats under conditions of simulated weightlessness.

• **Cardiac Arrhythmia.** In 1987, the flight of cosmonaut Aleksandr Laveikin was cut short because his heart began to beat erratically during exercises. Americans on both Apollo 15 and Skylab 2 also developed mild arrhythmia. Why? Nobody knows. Perhaps it's caused by an electrolyte imbalance, hormone shifts, or fluid-volume changes.

• **Heart Shrinkage.** In space, the heart has an easy life—no strenuous exercise to make it pump with vigor, no gravity to work against. Result: Its muscles relax, slow, and shrink. The left ventricles of two Skylab 4 crew members, who orbited for 84 days, lost nearly one-tenth of their size.

So far, heart shrinkage has caused little concern. If the result is simply fluid loss, it's no big deal; the fluid is replaced within a month or two of returning to Earth.

But Houston's Baylor College of Medicine cell biologist Margaret Goldstein is not so sanguine. When, through an electron microscope, she looked at cells from rats that had remained in orbit 14 days, she saw a noticeable loss of tiny muscle fibers called myofibrils, resulting in reduced cell size. "At some point the cells can get so small they can't function, and then they die," she says. "That's dangerous. Other muscles can repair themselves, but those of the heart haven't that ability."

• **Blood-Pressure Fluctuations.** Spaceflight can impair the body's blood-pressure-regulating reflex, causing changes similar to those that occur in Earth-bound people before they have heart attacks.

To study this reflex, Dr. Francis Andrew Gaffney, a payload specialist on the SLS-1 mission, flew with a catheter inserted into a vein in his arm. A sensor threaded through his blood vessels measured blood-pressure changes in the large veins near his heart during the first four hours of the flight—including the transition to weightlessness that occurred nine minutes after liftoff. Gaffney experienced a much more rapid drop in cen-

LOPING ON MARS

Near the center of Hangar 210 at NASA's Ames Research Center squats a 5,000-gallon vat of 85.5°F water. Inside the tank is Dava Newman's underwater treadmill, and with it she has concluded some fascinating things about getting around on Mars. For example: The best gait is a lope.

Newman is searching for basic data on how human movement and energy consumption will differ in reduced gravity. The data will help in the design of space suits, in astronaut training, and even in habitat design.

Newman is only 28 years old, but she probably knows as much as anyone on Earth about Mars-walking. She studied aerospace engineering, then earned master's degrees in aeronautics/astronautics and space policy. And now she's closing in on a doctoral degree in aerospace biomedical engineering from the Massachusetts Institute of Technology. Impressive.

So is her machine. She got the idea when she heard about the \$6 million NASA tank, called the Neutral Buoyancy Test Facility, built primarily for testing space suits. (Two old moon suits stand guard today beside the vat—empty, stiff, and vaguely menacing, like last year's cicada skins.) Newman was awarded a fellowship that allowed her to design the treadmill, and for the past four years she has been plopping scuba divers into the tank for workouts.

Her most surprising finding is that getting around on Mars will probably be easier than on the moon. With one-sixth the gravity of Earth, the moon requires an astronaut to expend energy maintaining balance. But Mars, with one-third of Earth's gravity, exerts a gentle downward tug that provides traction and stability.

"On the treadmill, Mars is the most comfortable [gravity] level," says Newman. "At lunar gravity, subjects tend to flail around a bit and take uncoordinated

Walking underwater while wearing weights, the author experiences the reduced gravity of Mars.

steps." Most subjects, in fact, use less oxygen at martian gravity than at Earth's higher gravity. That means smaller air tanks for space suits, altered thermal controls, and less fatigue. And the loping gait means redesigned space-suit joints.

Another thing that Newman is looking for is what she calls the "g" threshold: "In a shuttle's microgravity, we use our small muscles—primarily our arms—to move around. But in Earth gravity we use our legs. What is the crossover point when we become terrestrial? When does it become more efficient to start walking?" Answers will come with the next test series.

After producing a scuba certificate, updating my pilot's physical, and reading a 48-page safety manual, I stood in the chilly air of the open hangar while Newman and her team prepared me for a plunge into the tank. A face mask would provide air pumped down from the surface. It would also suck up expelled air, monitoring it for oxygen intake and carbon dioxide exhalation. A harness held weights, 60 pounds of them, strategically placed at my body's balance points, adjusted to mimic underwater the gravity of Mars. A wireless vest pressed electrodes to my chest. They would pick up my heartbeat, storing signals that would later be transferred to a computer.

In the tank, beneath the treadmill belt, four load cells would measure my footfalls. Meanwhile, a video camera would record the paths of reflectors stuck to my left arm, leg, and side. Later, all the data would be combined to produce a stick figure on Newman's screen, trotting along with my personal gait.

Submerged and standing on a moving belt, I found myself relearning what I knew about walking. Newman watched through a window, controlling the treadmill's speed. "How ya' doing?" she asked in my headphones. "You OK?"

Sure I was. I walked comfortably at a 1.5-mph pace, but somehow I had lost weight, and the water resistance seemed like a heavy wind. Newman gradually increased the speed, until at about 3.4 mph I started loping. I took longer and longer strides, sailing over the martian plains, leaping graceful as a gazelle over imagined boulders, settling easily into a speed of 5 mph or so.

I looked through the window at Newman. She was scowling and pulling her headphones away from her ears—and I realized I was laughing loudly into my mike. And looking forward to trying out the technique on Mars.—R. G.



COURTESY OF NASA

Within hours of liftoff, blood accumulates in an astronaut's head, neck, and torso. The body perceives this as an increase in blood volume and responds by destroying up to 16 percent of the blood.



gravity suits during atmospheric reentry somewhat alleviate this effect.

Another possible solution to the problem of blood-pooling was tested on the USML-1 mission last June. The Lower Body Negative Pressure (LBNP) device is an inflatable cylinder that seals around an astronaut's waist. A vacuum gradually decreases pressure in the LBNP unit, drawing fluids to the lower body.

•**Kidney Filtration.** The filtration rate increases, while plasma flow decreases. That may be a formula, says Dr. Carolyn Leach-Huntton of NASA's Johnson Space Center, for kidney stones.

•**Blood-Cell Changes.** Hemoglobin (red-cell) counts can drop by a third as a result of reduced bone-marrow production, causing a condition known as "space anemia." Also, the cells them-

tral blood pressure than was predicted by researchers.

•**Body-Fluid Shifts.** On Earth, blood tends to pool in the lower torso and legs. In space, it spreads out, moving toward the upper body, puffing the face and sometimes stressing the heart. Another effect: loss of fluid through urination, because pressure-monitoring sensors in chest arteries

note a surplus of fluid and shunt it away. Blood volume drops within hours of takeoff—up to a tenth the first day. Dehydration results.

So far, no negative effects from fluid shifts have appeared in space; but back on Earth, astronauts often suffer from dizziness and fainting when they stand up to walk. Drinking salt solutions and wearing pressurized anti-

TALES CHAMELEON SKIN CAN TELL

While space shuttle experiments get all the attention, unmanned rockets are now routinely—and cheaply—lifting research projects into space for short-term microgravity research. A typical experiment begins at 1:23 a.m. on Nov. 16, 1991, at the White Sands Missile Range in New Mexico. Len Epp—a tall, thin, pigment-cell biology specialist at Mount Union College in Alliance, Ohio—methodically snips chameleon skin into one-eighth-inch squares. Using tweezers, he drops each square into a milky-plastic vial shaped like an inverted T.

In a few hours his experiment will blast aloft on NASA's *Consort 4* sounding rocket. Then he'll know.

The plastic vials are lined up on a Penn State BioModule, a robotic minilab developed by a scientist at the university's Center for Cell Research—one of NASA's centers devoted to the commercial development of space. The BioModule, smaller than a brick, automatically mixes fluids at preset intervals. It's the only space-going device, says Epp, that can release two separate fluids into a third.

The lizard bits will float in one solution, will be flooded with a second liquid during the microgravity phase of the flight, and then, still weightless, will be fixed with a third fluid.

Working on the BioModule with Epp is Elaine Kunze, a senior research aide at Penn State. Wearing a pair of silver earrings shaped like chameleons, she gently stuffs the slender necks of the vials with balls of glass wool the size of peppercorns. Soon she'll top off the solution and squeeze on the stoppers.

•1:52 a.m.: Kunze and Epp hand the minilab to Roy Hammett, the biochemist who designed it. He finishes the assembly, tests it, and at 3:07 a.m. passes it to NASA technicians to be loaded into the rocket.

The question that the chameleon skins may answer is this: Do some sub-cellular biological processes stop working under near-weightless conditions? If so, maybe that will help explain why astronaut bones fail to absorb calcium and grow progressively weaker.

Skin from lizards commonly known as chameleons (actually, they're American anoles) makes for a handy tester. A bored chameleon sitting comfortably in the sun is brown, but two fighting males usually change to battleship gray. The winner turns apple green, while the loser becomes a sickly yellow.

The changes result when pigment-cell granules are driven this

way and that—through processes nobody quite understands—by hormones. One is adrenaline; another is melanocyte-stimulating hormone, or MSH. "If you hit a section of skin with MSH," explains Epp, "you'll drive the pigment cells so that it looks brown. Put in adrenaline, and you'll turn it green."

At least on Earth.

•8:30:01 a.m.: The lizard-skin team is standing on bleachers, waiting for the launch of the \$2.1 million rocket, 50 feet tall but only as wide as an ash can.

•8:30:01: Blast-off. "I'm always surprised at how fast those sounding rockets—recycled guided missiles, really—go up," says Epp. "Like a fireworks rocket."

As the missile rises, the two short arms of the T-tube vials remain tightly closed at the inner ends. One arm of each T holds adrenaline; the other, fixative. In the long center leg, brown skin bits float in a solution of weak MSH.

•8:31:03: Thrust stops, and the assembly continues to lift, essentially weightless. Almost 185 miles above the desert, the thousand-pound, 12-foot payload coasts smoothly in a perfect parabola.

•8:36:10: An onboard computer blinks, and suddenly, along the row of vials, spring-loaded solenoids pop, opening the ends of the tubes holding adrenaline. Rams flatten the tubes, squirting the liquid to the center. The event is telemetered to recorders back at the base.

There, Hammett, at his bench, is duplicating the sequence precisely. Later, when the team opens the ground-based unit, they'll note that the skin has turned green—as expected.

•8:38:02: Still in microgravity—and now the second set of solenoids blows. From the other leg of the T-tubes, fixatives squirt in, killing the chameleon tissue and halting the action.

•8:44:11: With a metallic thump, the payload, already telemetering its location, parachutes to Earth. A half-hour later, the helicopter crew loads it for the 53-mile return trip to White Sands.

•10:58:15: NASA technicians have finished photographing each screw, bolt, and plate as it is removed, and finally the skin team begins taking apart the BioModule. They snip off the T-tube legs, draw out the liquid with Q-tips, and lift out the skin bits.

If the skin is green, that means the microscopic processes that move pigment particles can operate in microgravity. Brown skin means something doesn't work—with far-reaching implications.

Epp holds the bits up to the light. They're brown.—R. G.



D. HELICZER/M. KATZ/ GAMMA LIAISON

selves can mysteriously develop odd shapes—bumpy spheroids called echinocytes. Lymphocytes (white cells) become sluggish, slowing in activity by nearly half in some cases. It all leads to a general weakening of the immune system that could mean susceptibility to stray microorganisms lurking in capsule crevices.

• **Motion Sickness.** Also called "space adaptation syndrome," its symptoms are nausea, sweating, headaches, lethargy, appetite loss, and dizziness. Tiny stones in the inner ear cause the problem; they tell the brain that the body is tilting, while the senses of sight and touch say it's not. One helpful preflight training exercise: strap astronauts into spinning chairs. Drugs such as promethazine, an intramuscular treatment, help reduce the symptoms in most cases. And on long space trips, the mind usually adapts to the environment, developing the equivalent of sea legs.

The long list of potential problems seems ominous. But optimists take comfort in the results from the June 1991 SLS-1 mission, the most detailed attempt yet to study microgravity's medical effects. The biggest surprise was how quickly most changes occurred—almost immediately upon launch. The most reassuring news: So far, says Dr. Ronald J. White, chief scientist of NASA's Life Sciences Division, assessments have uncovered no biological reason why a Mars flight couldn't be successful.

Meanwhile, scientists are studying countermeasures that could minimize the risk of space travel. The 1990 National Research Council report on space exploration urged NASA to develop "artificial gravity" for future expeditions. Artificial gravity might be generated by two connected spacecraft rotating around each other, or by a spinning capsule—like the one originally planned for the space station.

A few hours of artificial gravity a day might be enough to prevent unwanted effects. In a study done last year at NASA's Ames Research Center, volunteers were confined to bed for four days with their heads tilted down at a six-degree angle—inducing some of the physical changes experienced in space. The study showed that the volunteers could avoid these changes by standing quietly for 15 minutes each hour over a 16-hour period.

"The question we must answer is both practical and basic: How much gravity, how often, and for how long?" asks Dr. Joan Vernikos, the study's principal investigator. "We must know whether humans need gravity 24 hours a day to remain healthy."

WALKING ON A WALL

I gaze up at the ceiling as technicians adjust the bungee cords supporting me. I'm dangling from the cords like a marionette, lying face up, bobbing slightly while long springs pull me toward a vertical treadmill mounted on the wall. The researchers periodically turn it on, and I begin running while a computer measures my foot thumps, and a video camera records my gait. I've been in this harness an hour now, and the sweat has begun to trickle back into my helmet.

The apparatus is a microgravity simulator and exerciser, located in the basement of a Penn State gym. The researchers are gathering information on how astronauts might jog in space. Jogging is probably the best way to stop calcium loss, one of the most serious problems for astronauts who stay in space for extended periods.

The machine starts up again. "Stand up straight," says Brian Davis, the tall, skinny chief researcher on the project. "Don't lean forward. Try to keep in the center. Can't you run with more coordination?"

Davis calls his device a Zero-gravity Locomotion Simulator, or ZLS, and the data he gathers from my flailings will be added to that from at least a dozen other subjects. His objective is to determine the optimum treadmill design and speed, for eventually his findings will likely lead to a powered shuttle treadmill, and later, perhaps a unit for the space station.

The calcium-loss problem—osteoporosis—has everyone in the space program concerned. Cosmonauts aboard Salyut-1 suffered a 17 percent calcium decrease in their leg bones in only 24 days. A Mars trip would last at least a couple of years, and physiologists worry that astronauts will step out of their craft on legs that will splinter.

Drugs (such as fluorides) aren't much help, and some have serious side effects. Dietary supplements of calcium do virtually nothing. Rubber "penguin suits" favored by early cosmonauts—which force the wearer to exercise because virtually every movement becomes labored—promote muscle tone and a healthy cardiovascular system, but do nothing to stop calcium from draining away. Even rowing or bicycling doesn't solve the problem.

The reason, apparently, is that these types of exercise are devoid of impact jolts, and when lower extremities aren't periodically jarred, calcium leaches out to be urinated away.

A powered treadmill might solve the problem. Preliminary animal studies show that when the leg bones are jarred, calcium is retained. Shuttle astronauts have used a passive treadmill, but only a powered unit can provide jolts.

NASA provided funds for Davis, a specialist in biomedical engineering, to build his treadmill at Penn State's Center for Locomotion Studies. He collaborates with the center's director, an Englishman named Peter Cavanagh, as well as three other engineers—Randall Bock, H. J. Sommer, and Andris Freivalds.

In their lab, I float a yard above the floor. Holding me up are bungees averaging 30 feet long. Each cord supports a different part of my body—two for each leg, others holding up my arms, torso, and head. Finally, I'm attached to the wall by a set of springs. My footfalls are measured by a Kistler forceplate (ordinarily used to gauge such things as head impacts on dashboards) just under the treadmill belt.

Now Davis begins tightening the springs that pull me toward the treadmill, ratcheting me so tight I think my legs will buckle.

He laughs. "That's one thing that always surprises me," he says. "Every subject is the same: When I tighten the cords to only 20 percent of Earth weight, it feels like one g. You're at only 60 percent now. In space, we must include some method for objectively measuring tension. You just can't tell by feel."

My run is finally finished, and now, off the contraption and on a support table, my limbs feel extraordinarily heavy, as though weights are still attached. "That too always happens," says Davis. "One subject actually thought that we had tied down his legs to the support table. You adapt to feeling weightless that quickly. Now you're reading the tape."

Later this year, Davis hopes to test experienced astronauts on the treadmill, running at various gaits at various weights. They'll compare the feeling with that remembered from space.

And then, space itself. "When we've come up with the most effective form of exercise," says Davis, "the goal is to implement that on an actual long-term mission—say, one of a month's duration. We'll measure calcium before and after, and see if we have cut down its loss—maybe even to zero."—R. G.



In this microgravity simulator and exerciser, elastic cords apply an upward force equal to the downward pull of gravity.

GREG GREGG

MINIVANS TO THE MAX

**We test the tallest,
the longest, and
the widest. Which
is the best?**

BY DAN McCOSH



DODGE GRAND CARAVAN ES Perhaps



MERCURY VILLAGER LS Mercury's trademark light-bar nose, digital instrumentation, and



VOLKSWAGEN EUROVAN MV The upright driving position and flat steering-wheel angle would make Ralph Kramden feel right at home.





NISSAN QUEST GXE A handling suspension package gives this minivan near sports-carlike agility, but you'll spill the drinks in the cupholders.



the ultimate bread box, with a driver-side air bag, and best all-around people-and-their-gear mover.



other luxury touches set it apart from the rest.

The three new minivans introduced this year are close enough to Chrysler's original concept that it's tough to tell them apart at the far end of a parking lot. But these well-thought-out clones are facing a formidable challenge: to improve on a vehicle that is not only the third-highest volume seller of any type (including all of its derivatives) in the United States today, but one that also manages to out-sell all of its competitors combined.

At first glance, Chrysler's minivan is essentially a bread box on wheels—so simple in design and execution that duplicating it seems laughably easy. But so far it's defied imitation, as other automakers try to figure out why this minivan is one of the most popular vehicles on American highways.

What makes the automakers' chase even more fascinating is that the minivan has spawned a wide variety of ideas on how it could be designed, both mechanically and cosmetically. From varying proportions, engine placements, and even basic body structures, just about every variation has been tried in the minivan design book. Yet none has captivated the public quite like the Chrysler.

Volkswagen first popularized the minivan concept with its Beetle-based, rear-engine microbus introduced in the United States in 1950, a vehicle that achieved cultlike status among the Woodstock generation. For 1993, VW is introducing the EuroVan, its first front-drive minivan and the tallest of our test group. Nissan has tried twice before with two versions of its smallest minivans, but both failed to catch on in the United States. Now the Japanese automaker is collaborating with Ford

to build the minivan twins Nissan Quest and the Mercury Villager—the widest of the four we tested—at Ford's Avon Lake, Ohio, assembly plant. To see how these new contenders fare, we lined them up with the longest minivan—the Dodge Grand Caravan ES, the reigning leader in an increasingly crowded class.

After decades of trying alternative design strategies, the latest Volkswagen and Ford/Nissan efforts end up more or less where Chrysler started: Besides now possessing the same fundamental box configuration, VW and Ford/Nissan also share the Chrysler merits of a transverse engine driving the front wheels and a flat, low floor following along behind. All of these vans are designed to carry people, not haul cargo.

In Volkswagen's case, the design change meant discarding one of the last remaining logical applications of a rear engine and transaxle in the auto business. The VW EuroVan replaces the Vanagon, a minivan that had evolved over the years from the tippy-toed microbus. This vehicle struggled in the early years with a 25-horsepower air-cooled engine driving the rear wheels through a weird double-reduction gear set that put the centerline of the rear hubs even with the bottom of the floor pan. The setup yielded enviable ground clearance but contributed to poor stability. Later, the hubs disappeared as power increased, the swing-axle rear suspension was changed to a semi-trailing arm, and eventually the flat-four engine became water-cooled. The last generation of the Vanagon still enjoyed one solid attribute from its rear engine—good weight distribution that only improved when cargo was added. It still had the major drawback, however, of forfeiting all of the space behind the rear (third) seat to a high shelf that covered the engine.

Given a clean sheet of paper to design the new front-drive EuroVan, VW designers unfortunately didn't start with a good eraser for their mind-set. The transverse engine and front-wheel drive clear the floor to the rear, but nostalgia for that package shelf apparently led the EuroVan's designers to raise the floor under the two front seats some six inches above the rear floor pan. This makes for an awkward step-in height for the driver and front-seat passenger. It also reduces occupants' headroom (and for some, legroom) and prevents sliding long boards up under the front seats—a trick minivan-owners quickly learn in order to get the tailgate closed. Apparently, the rise in the floor is necessary to make room for the front suspension and steering gear, an outgrowth of the extreme forward placement of the front seats. This also necessitates an awkward, near-vertical angle for the steering column and wheel. As a result, the EuroVan's driving position is pure Ralph Kramden.

With all this lost, the gain is one of the largest cubic measures for the space *behind* the two front seats of any van in its class. It's even possible (we tried it) to load a 4x8 sheet of plywood through the cavernous rear door and carry it horizontally inside. Covered storage boxes behind the rear seat are good for small items, and a rear seat folds out into a rudimentary bed or easily slides out altogether for a clear back floor. The rear-facing seats also are easily removed, although clearing out a full cargo floor demands some unbolting of both the rear seat tracks and the storage bins. There are other features that lean toward on-highway touring or even camping: Rear-seat passengers get conversational seating and an ingenious fold-up table that might make this the ultimate car-pool vehicle.

With more power, the EuroVan would be great for a road trip, but its 109-hp in-line five-cylinder is barely adequate for around-town driving; even unloaded it takes 16.5 seconds to accelerate to 60 mph. The EuroVan also tips the scales at better than two tons, and the roof is more than six feet off the ground. That kind of frontal area needs some serious horsepower to push through the air. The lightweight 2.5-liter engine gets significantly less fuel economy than the Grand Caravan's 3.3-liter 150-hp V6, and, surprisingly, demands premium gas.

Because the old Vanagon was one of the best-handling minivans, it is even more surprising that the EuroVan's truck-based chassis balks at hard cornering. Admittedly, that could be an advantage—assuming there's a card game going on at the folding table. All in all, the EuroVan provides motor-



The quartet, in its native habitat (from left): Mercury Villager, Volkswagen EuroVan, Dodge Grand Caravan, and Nissan Quest.

home-style performance in a class of vehicles that lately is becoming both quicker and more agile.

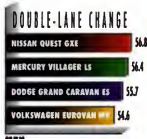
The new Nissan-engineered Quest GXE is at the opposite end of the handling spectrum from the EuroVan, reaching near-sport-coupe speeds on the skid pad and winding through the slalom about one mph faster than the second-place Dodge Grand Caravan. It's of more than academic interest that the Mercury Villager, virtually identical in most respects to the Quest, finished third and fourth in these same categories. The difference is in the handling suspension package that was fitted on the Quest but not on the Villager—Good-year GA radial tires, stiffer springs, shocks, and a rear anti-sway bar. The same package is available on the Villager, but we requested different equipment in order to compare the optional suspension.

The new Nissan and Mercury mini-

vans are the products of a joint venture between Ford and the Japanese automaker. The bulk of the engineering and design work was accomplished by Nissan, while the van is manufactured in a Ford truck plant in the United States. Unlike the Ford/Mazda tieup that produced two distinctive vehicles—the Ford Probe and the Mazda MX-6 sports coupes—the Villager and Quest vans are virtually identical, save for exterior and interior styling.

The basic chassis sections for the Quest and Villager are derived from the Nissan Maxima sedan, a far more sophisticated setup than the K-car-derived underpinnings of the Grand Caravan. The differences show up at railroad crossings and on winding roads when the pavement turns rough.

Short of flat-out handling ability, the Quest and Villager are pleasant vehicles on the highway, with good visibility, comfortable seating, and responsive steering. Still, when empty, the Villager/Quest vans are slightly worse



performers than the Grand Caravan. Despite a slight horsepower edge from a smaller-displacement (three-liter) V6 engine, the Villager's all-up curb weight is 4,043 pounds and the Quest's is 4,083—200-plus pounds heavier than the Dodge; this cuts into acceleration and fuel economy. The Villager and Quest, however, have full side-intrusion door beams, hence meeting all current passenger-car crash standards. (Minivans are required only to meet light-truck standards, which currently do not mandate features such as head-rests.) Strangely, despite the emphasis on crashworthy construction, the designers didn't follow Chrysler's lead in making a minivan air bag standard.

Nissan notes that it designed the chassis structure with the aid of a Cray supercomputer, a commonplace technique these days that apparently missed predicting a strange harmonic vibration that causes the right-hand seat in the center row to shake mysteriously at certain speeds when the

minivan is empty. Otherwise, the structure is tight and quiet.

Unlike the sometimes uncomfortable rear-facing seats in the EuroVan, the Quest/Villager vans have straightforward five- and seven-passenger arrangements, with the main twist a sliding track that allows the rear seat to be pushed forward to quickly enlarge the cargo space at the rear. This is a clever idea, but the mounting precludes removing the seat altogether, and therefore limits cargo room when you want to haul something bulky like a sofa.

Exterior styling is one feature that sets off the Villager/Quest more than any other. Modern, aerodynamic, and considerably more functional than other slope-nosed efforts that destroy forward visibility—the GM APVs are a notable example—the basic envelope is highly successful and a pleasant alternative. Still, it demonstrates the problem inherent in anything but a basic slab-sided approach. The curved side and the downward slope of the roofline

take away substantial interior volume at forehead-level. As a result, passengers riding shotgun in the back occasionally end up banging their heads on the sides. This contradicts the advertised interior volume to the point where few passengers would agree that the Quest/Villager twins are actually larger inside than the Grand Caravan—even though the objective numbers say otherwise. The result is a somewhat claustrophobic effect, especially when compared with the roomy-feeling Dodge.

With all of the competition, Chrysler hasn't been standing still. But "The Minivan Company" hasn't been anxious to make dramatic changes, either. Our test Grand Caravan ES is representative of a generational updating done in 1991. Today's minivan is slightly more rounded than the first generation, but not too rounded. The front suspension has been tuned and improved, and the

steering is more linear. It is one of those exercises in evolutionary development—which translates into trying not to mess up a good thing.

The basic Chrysler design is actually not as simple as it looks. One key factor to its success remains the seating position of the driver. The front floor is about at curb height, the wheel housings are forward, and the front bucket seats are virtually at chair height—all making it extremely easy to enter and exit. The steering wheel is at a comfortable angle, and the nose is short, crash-worthy, and visible. Visibility from the driver's seat, in fact, ranks with the best of any type of vehicle on the road. This is partially due to the relatively deep windows that surround the passengers. To accomplish this, the placement of the engine and front suspension relative to the grille and firewall is critical—a carefully thought-out strategy that, not coincidentally, matches the dimensions of the old K-car platform. Exactly what will happen now that the old K-car is being phased out makes for interesting speculation about the future design of the Chrysler minivan.

Meanwhile, although it takes a while to sink in, this big box is a masterpiece of ergonomics. The odd pieces of seating proportion, visibility, instrumentation,

(Continued on page 97)

THE CHALLENGERS AND THE CHAMP

This comparison test of new minivans from Nissan, Ford, and Volkswagen, doing battle against the established cream of the crop, the Dodge Grand Caravan, brings some interesting facets to light. The Volkswagen EuroVan MV, the most complete and most expensive version you can buy, is so far adrift from the American idiom of family vans that it just doesn't figure. It is slow, cumbersome, noisy, and just can't run with the others. But the EuroVan's mobile-office interior layout made it the most fun to hang out in.

The stylish new Nissan Quest, even though it was the heaviest of the lot, displayed amazing grace under pressure, winning the handling and braking derbies. Mercury's Villager, a virtual twin to the Quest, had still more style and more luxuries such as digital instrumentation. But our test Villager lacked the extra suspension pieces that are standard on the Quest—the handling suspension is optional on the Villager—so it didn't handle or stop quite as well. The Villager also shared some of the Quest's noise vibration and harsh ride problems.

Its lack of sliding seats aside, though, the quick, lightweight V6 Dodge Grand Caravan still seems to have the best combination of looks, brawn, size, and features the market is looking for.—Jim McCraw

POPULAR SCIENCE TEST RESULTS

Dodge Grand Caravan ES

Mercury Villager LS

Nissan Quest GXE

Volkswagen EuroVan MV

ACCELERATION AND HANDLING

0-30 mph (sec.)	5.0	4.2	4.1	3.8
0-40 mph (sec.)	14.5	12.1	11.8	11.3
0-50 mph (sec.)	7.5	6.1	5.8	5.2
50-70 mph (sec.)	11.4	7.9	7.2	7.8
(Double-lane change) (mph)	54.6	56.8	56.4	55.7
Skidpad (mph)	43.5	46.7	45.0	45.8
Road-holding (g)	0.71	0.78	0.70	0.73

BRAKING

Cold (ft.)	193	188	159	170
Warm (ft.)	167	151	153	155
Wet (ft.)	170	156	164	163

INTERIOR NOISE

Idle (dB)	56	43	46	49
40 mph (dB)	72	68	68	68
60 mph (dB)	78	76	74	78

SPECIFICATIONS

Engine	2.5L I5 SOHC	3.0L V6 SOHC	3.0L V6 SOHC	3.0L V6 OHV
Valve train	2 valves/cyl.	2 valves/cyl.	2 valves/cyl.	2 valves/cyl.
Power (hp@rpm)	109/4,500	151/4,000	151/4,000	150/4,800
Torque (lb.-ft.@rpm)	140/2,200	174/4,400	174/4,400	185/4,600
Compression ratio	8.5:1	9.0:1	9.0:1	8.9:1

Transmission	4-speed automatic	4-speed automatic	4-speed automatic	4-speed automatic
Final drive ratio	5.28:1	3.84:1	3.84:1	2.49:1

CHASSIS

Front suspension	Independent, unequal-lough control arms, torsion bars, anti-roll bar	Independent, MacPherson strut, coil springs, anti-roll bar	Independent, MacPherson strut, coil springs, anti-roll bar	MacPherson strut, coil springs, anti-roll bar
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Rear suspension	Independent, semi-trailing arm, coil springs, anti-roll bar	Rigid axle with semi-elliptical leaf springs, anti-roll bar	Rigid axle with semi-elliptical leaf springs	Rigid axle with semi-elliptical leaf springs, anti-roll bar
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Steering gear	Back-and-forth, power assist	Back-and-forth, power assist	Back-and-forth, power assist	Back-and-forth, power assist
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Turning circle (ft.)	37.7	38.7	38.7	42.5
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Brakes (fr., rear)	Vented disc, drum power assist	ABS; vented disc, drum; power assist	ABS; vented disc, drum; power assist	Vented disc, drum; power assist
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EPA MILEAGE

City	17	17	17	18
Highway	19	23	23	23

DIMENSIONS

Wheelbase (in.)	115.0	112.2	112.2	119.3
Length (in.)	184.6	189.9	189.9	192.8
Width (in.)	72.4	73.7	73.7	72.0

Height (in.)	74.8	67.4	67.4	64.7
Curb weight (lb.)	4,058	4,083	4,043	3,847
Distribution % (front/rear)	62/38	57/43	58/42	58/42

Fuel tank (gal.)	21.1	20.0	20.0	20.0
Interior volume (cu. ft.)	159	156	154	152
Cargo volume, max/min (cu. ft.)	195/48	126/11	126/11	141/36

PRICES, PARTS, AND LABOR

Base price	\$21,850	\$21,450	\$21,799	\$22,245
Price as tested	\$23,510	\$23,820	\$25,121	\$23,058

Major options (over \$100)	Automatic transmission \$895; convenience package (power windows, central locking, cruise control) \$745	Performance package (3,500-lb. towing, ABS, aluminum wheels, heavy-duty battery and radiator, suspension components) \$930; power sliding sunroof \$825; CD player \$615	Leather upholstery \$865; power sunroof \$775; quad bucket seating \$595; preferred equipment package \$345; keyless entry system \$301; digital instrument cluster \$244; power passenger's seat \$194	Luxury value package \$400; luggage rack \$143
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Repair: Parts/Labor*	\$104/31	\$104/23	\$104/23	\$104/23
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Front brake pads	\$98/48	75/63	60/58	57/50
Front shock/insert	450/29	273/32	230/36	230/36

Alternator	75/121	51/130	65/95	64/97
Water pump	394/111	229/153	406/90	215/90
Windshield	129/24	120/14	92/26	70/14
Headlamp assembly				

*Labor costs reflect manufacturer's flat-rate time allowance multiplied by typical dealership labor rates per hour.

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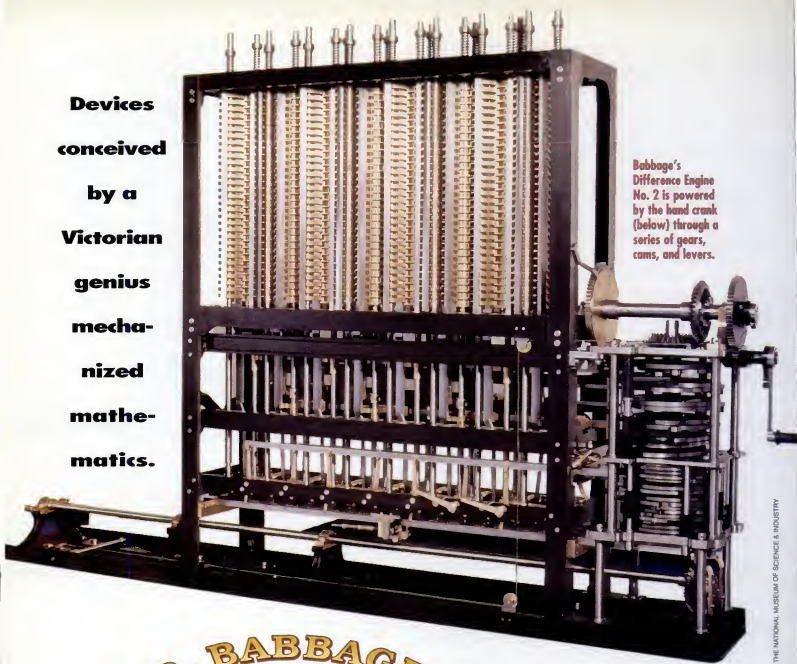
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**Devices
conceived
by a
Victorian
genius
mecha-
nized
mathe-
matics.**

Babbage's
Difference Engine
No. 2 is powered
by the hand crank
(below) through a
series of gears,
cams, and levers.



THE NATIONAL MUSEUM OF SCIENCE & INDUSTRY

MR. BABBAGE'S
WONDERFUL
Calculating
Machine

BY STUART F. BROWN

Clacking, ratcheting, and dully ringing with the music of precise bronze and steel clockwork, numbered cogwheels on upright shafts begin to move as an engineer in a white lab coat turns a reluctant hand crank. The engraved wheels click into place one by one, reading out a 30-digit number.

More than 140 years after it was designed, Difference Engine No. 2—which was never built by its 19th century inventor—is finally up and running. And it works. Comprising 4,000 parts housed in a cast-iron frame seven feet tall and 11 feet long, the imposing machine has delivered the correct answer to a complex mathematical calculation.

English mathematician and far-ranging thinker Charles Babbage drafted the construction drawings for his automatic calculator between 1847 and 1849. Boggled down by financial and other troubles, however, Babbage wasn't able to build the machine he had conceived. For years,

historians assumed part of the problem was that metalworking technology of the mid-19th century was inadequate for producing the hundreds of complex, identical precision parts the engine required.

In order to test the technology hypothesis while commemorating the 1991 bicentennial of Babbage's birth, the Science Museum in London, guided by 20 original drawings in its collection, fabricated a working engine. The materials and machining tolerances used were the same as those available to the inventor. Although the museum employed modern automated equipment to speed production of batches of parts, the results show that the state of Victorian machining art could, after all, have been up to the task.

The idea of an automatic calculating machine held great appeal to scientists like Babbage and to the bankers, navigators, engineers, and others who routinely needed to perform large arithmetic procedures. The printed mathematical tables of multiplication, division, and logarithms they relied upon as calculating aids were far from ideal. Bound into volumes of endless columns of figures that were tedious to use, the tables also contained errors that crept in through mistakes in calculation, transcription, and printing. Capturing the rules of math in immutable metal would banish these potentially disastrous vagaries, which could cause ships to run aground or accountants to make huge financial blunders.

Babbage began working on such machines in 1821, managing after 11 years of great expense and frustration to produce one-seventh of the calculating section of Difference Engine No. 1, an assemblage of 2,000 precision parts that functions to this day. Doron Swade, the museum's senior curator of computing and control, calls the mechanism "the first known automatic calculating device and one of the most celebrated icons in the prehistory of computing." If completed, the entire engine would have had about 25,000 parts and weighed several tons.

Difference Engine No. 2 represents an evolution from its predecessor that uses a simpler, more efficient mechanical design. Both engines were designed to incorporate automatic printing mechanisms for putting accurate mathematical tables onto paper. The museum eventually plans to construct a printer for Engine No. 2; it will consist of about 4,000 additional parts.

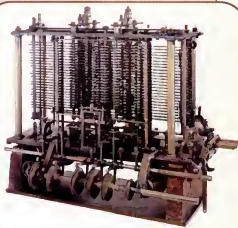
As their names suggest, these engines operate on the method of finite differences, a principle by which the value of complex mathematical expressions can be found through a series of

JUST LIKE A COMPUTER

Looking beyond his first Difference Engine, which was an automatic calculator that functioned according to a fixed additive sequence, Babbage began in 1834 to think about a more sophisticated general-purpose machine, which he called the Analytical Engine. It was intended to perform algebraic functions.

Like a modern computer, the engine would be programmable. Babbage borrowed the technique of storing instructions on punched cards from the French Jacquard loom, which automatically wove elaborate motifs into textiles. He designed a system for reading information on the cards by passing rods through their perforations. Other sections of the machine included a "mill" where arithmetic processing occurred and a "store" that held calculations-in-progress.

Ada Lovelace—the mathematically gifted daughter of Lord Byron and author of an insightful paper on Babbage's advanced design—said at the time, "The Analytical Engine weaves algebraic patterns just as the Jacquard loom weaves flowers and leaves." Had the engine been completed, it would have been as much as 20 feet long and would almost certainly have required steam or water power to spin its vast mechanical workings.—S. F. B.



A section of the Analytical Engine was being built when Babbage died in 1871.

additions, a much less complicated mechanical challenge than multiplying or dividing. If a total of 8,000 components are required to calculate and print by this method, imagine the complexity of a machine conceived to tackle long division head-on.

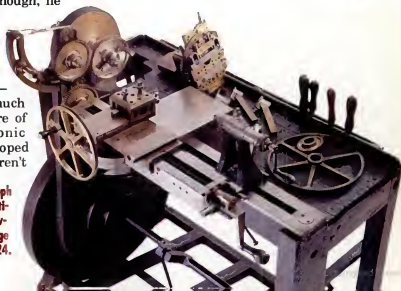
Babbage's demand for large quantities of intricate metal parts helped expand the limits of manufacturing technology. Working with a brilliant machine-tool builder named Joseph Clement, Babbage developed many special tools and jigs, and later explored sheet-metal stamping and pressure die-casting processes for making interchangeable components. Surviving parts built for the Difference and Analytical engines (see box) are magnificent in their form and finish.

Charles Babbage was much more than a number-cruncher and machine designer—he was also a philosopher, writer, political economist, and socialite. Today, though, he is remembered principally as one of the grandfathers of the computer. Curiously, his ideas—which presage much of the architecture of the first electronic computers developed in the 1940s—weren't

widely known then to most researchers.

After Babbage's death, his son assembled a small model of Difference Engine No. 1, which he sent to Harvard University in 1896. Electronic computing pioneer Howard Aiken later came across the machine. "If Babbage had lived 75 years later," he said, "I would have been out of a job."

In his role as an innovator who invented things future scientists would have to recreate for themselves, Babbage remains a compelling figure in the history of technology. A recent historical science-fiction novel, *The Difference Engine* (Gibson and Sterling, Bantam, 1991), imagines a Victorian Britain where huge banks of government-owned Babbage machines clack through calculations governing the lives of the populace. And in the real London of 1993, the gleaming workings of Difference Engine No. 2 are on display for visitors to admire.



Machine designer Joseph Clement built this multi-purpose, treadle-powered lathe for Babbage in 1824.

'THE LITTLE ENGINE THAT COULD

**This four-cycle engine is lightweight enough
for hand-held equipment—and clean
enough for California.**

BY JUDITH ANNE GUNTHER

H

ere, claimed experts in the outdoor power tool industry, was a problem without a ready solution: How could they build a gas-powered engine small and powerful enough for consumers, yet sufficiently clean-burning to meet increasingly demanding legislation?

Now one manufacturer, Ryobi North America, the South Carolina-based subsidiary of the Japanese tool-maker, says it has an answer. Ryobi's CleanAir engine is a radically scaled-down 26cc four-cycle engine that deftly delivers one horsepower in an eight-pound package. And Ryobi is betting that this engine will heavily influence the hand-held outdoor power tools that consumers buy in the mid-1990s.

For decades, manufacturers have relied on two-cycle engines to power chain saws, trimmers, blowers, and other tools that require light weight and brute force, taking advantage of a power pulse with every crankshaft revolution ["Greener Pastures," July '92]. But such performance has its price—air pollution—and in 1990 the California Air Resources Board (CARB) established stringent emissions standards that will have to be met by all gas-powered utility products sold in that state. The CARB regulations, which take effect in two phases, 1994 and then 1999, have been criticized by some manu-

facturers as being too difficult to meet in a relatively short period of time. (Discussions are under way between CARB and manufacturers to move the first-phase deadline back by one year.)

How did Ryobi get the jump on the industry? Partly by making the project a priority item as early as 1989 and partly by pushing the limits of small-engine technology. The CleanAir engine circumvents the exhaust emissions problem inherent in a two-cycle engine mainly by employing its cousin, the four-cycle engine.

The project had sprung from a concept for a small-displacement, low-cost four-stroke engine that had been proposed to Ryobi in 1988 by Robert Everts, an Arizona-based engineer whose company produced the first working prototype. Commonly used in heavier lawn and garden equipment, a four-cycle engine fires its ignition on every other revolution and uses conventional poppet valves to control the flow of the incoming fuel-air mixture and outgoing exhaust; this helps reduce the chance that some fuel will escape unburned. And unlike many two-cycle engine designs, the four-cycle doesn't require that the lubricating oil be mixed directly with the gasoline, a major cause of the blue-smoke plume that routinely spits out of two-cycles.

"We started out with three criteria for this engine,"



says Ryobi senior vice president William McLay. "First, it had to meet California's emissions standards. Second, it could not be any heavier than current two-cycle engines. Third, it couldn't cost significantly more than high-end engines. And we feel that the CleanAir engine meets these parameters."

In theory, building a small four-cycle engine might not seem difficult, but in reality Ryobi faced numerous design and manufacturing hurdles. Today's small four-cycle engines normally weigh 40 pounds and generate about 3.5 horsepower. The CleanAir engine, in comparison, weighs just eight pounds and generates one horsepower. Such dramatic downsizing required smaller components; some parts, such as the valves, didn't exist and had to be designed and manufactured specifically for this engine.

Still, industry experts are cautious when discussing the engine. "There's no magic here," remarks Glenn Keller of the Engine Manufacturers Association in Chicago. While he acknowledges the difficulties in design, he sums that "Ryobi has just miniaturized everything."

A logical analysis in the broad sense, but, as additional research indicates, something of an underestimate of the cleverness of the Ryobi engine design. Such a simplistic engine-shrinking could certainly have produced the low

emissions levels and perhaps the necessary power output, but doubtfully could have done it at a competitive manufacturing cost. Here the CleanAir engine demonstrates some unique design solutions that give it a clear edge, at least for the time being.

"We are aware—at least it's rumored in the industry—that other manufacturers have made small four-cycle engines," McLay says. "But they're either polluting or very costly or too heavy." Likewise, tiny four-cycle engines used in another application—model airplanes—don't fit the bill for running trimmers and blowers. "That's a whole different power class," says McLay.

To operate a grass trimmer, he explains, a small four-cycle engine must turn at about 7,000 or 8,000 rpm—twice the speed of a mower-type engine. Increasing speed means increased heat, and possibly increased wear on engine parts. Although McLay won't reveal the metallurgy processes that were employed ("We hope it will take a while for our competitors to figure it out," he says), he does allude to alloys, heat-treating methods, and materials chosen for their lubricity.

To keep engine temperatures down, Ryobi engineers worked out an unusual two-piece cylinder head consisting of a lower casting that houses the combustion chamber and an upper section

that encloses the rocker arms used to open the valves. This design permits cooling fins to be placed strategically next to some of the hottest areas of the engine—the exhaust valve and bridge area between the valves.

For all of the development effort Ryobi invested in it, the CleanAir engine must still be competitive with other products if it is to sell in the 49 states that *don't* have emissions regulations yet. (The EPA is reviewing emissions data of so-called utility engines; nationwide regulations may be announced by the end of 1993.)

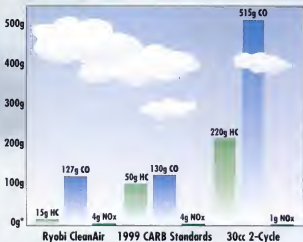
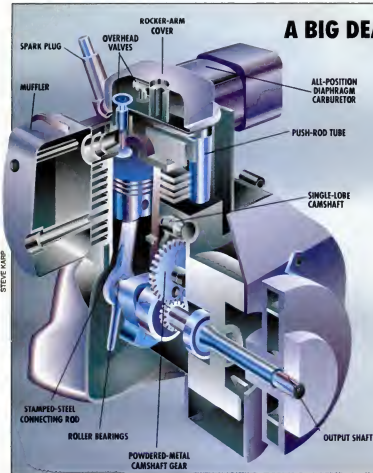
"Only certain people will buy a product because it is environmentally friendly," McLay acknowledges. Performance, he maintains, will be a major selling point.

The most significant benefit consumers will find is the more consistent power produced by four-strokes. "The characteristic of a two-cycle engine is that it has to be very high on the rpm curve to get the most torque output," he explains. "But a four-cycle has a flatter curve, so when the engine is working hard, it still produces the torque. As rpm drops, torque doesn't drop much at all."

Another plus inherent in a four-cycle engine is that it doesn't require a gas-oil mixture. Instead, lubricant is distributed by a dipper at the end of the connecting rod—the conventional

(Continued on page 96)

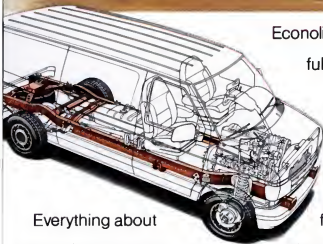
A BIG DEAL: SMALL ENGINE, LOW EMISSIONS



* EMISSIONS MEASURED IN GRAMS PER BRAKE HORSEPOWER-HOUR

Weighing in at just eight pounds, the 26cc four-cycle overhead-valve CleanAir engine generates one horsepower and meets California's 1999 emissions limits (see chart). Thanks to the all-position diaphragm carburetor and a roller-bearing-equipped connecting rod, the engine will run at any angle without incurring damage. To keep weight down, the CleanAir engine uses a cantilevered crankshaft, supported by bearings on one side only, and the piston runs on a flash-chromed cylinder bore rather than a cast-iron sleeve. Both the intake and exhaust valves are actuated by a single cam lobe.

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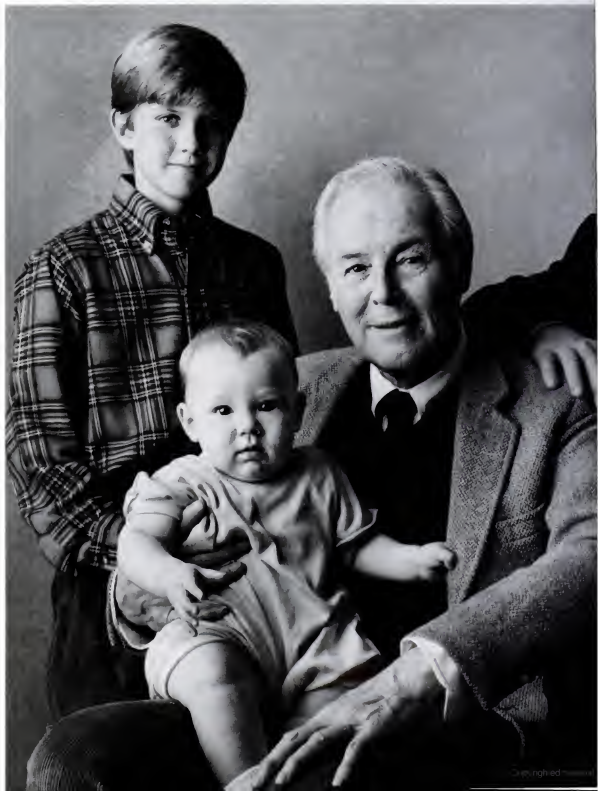
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The “growth cycle” of the prostate: from birth through later life.



As a male develops from childhood through maturity, his prostate grows, stops growing, and can then start growing again in later life. To help you understand the vital role the prostate plays, here are some important facts.

The prostate at birth

Only males are born with a prostate gland. It's located at the base of the bladder, as shown in the diagram.

At birth, a baby boy's prostate is about the size of an almond, and it remains that size throughout childhood.



The prostate at puberty

During puberty, the prostate doubles in size. Then it stops growing. This is normal. The prostate is preparing for its main role in life — helping sexual reproduction.

The prostate supplies the milky fluid that helps transport the sperm through the penis during ejaculation. The prostatic fluid also aids conception by providing support and nourishment for the sperm and helping to make the vaginal canal less acidic.

The renewed growth of the prostate at middle age

In most men, after age 45, the prostate starts to enlarge and may continue to enlarge for the rest of a man's life. This growth may be benign prostate enlargement, a noncancerous condition. A major cause is the activity of a key hormone.

By itself, benign prostate enlargement isn't a problem. But, the prostate gland surrounds a section of the urethra, the tube that carries urine from the bladder through the penis. As the prostate continues to grow, it can squeeze the urethra (like pinching a straw) and interfere with the normal flow of urine, causing uncomfortable and embarrassing symptoms.

The prostate in later life

Not every man develops an enlarged prostate. And in those men who have the condition, it is not always progressive.

However, prostate enlargement is a common medical finding. In fact, more than half of men over 50 have an enlarged prostate.

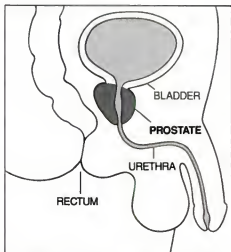
The urinary symptoms of an enlarged prostate

Among the symptoms commonly associated with an enlarged prostate are more frequent urination, especially during the night, or the sudden, almost uncontrollable urge to urinate. The added pressure on the urethra can also cause a weak, interrupted urine stream, a sense of the bladder not emptying com-

pletely, leakage, and difficulty in starting urination. It can even result in total blockage, a serious condition.

Why you should consult the doctor

Symptomatic benign prostate enlargement can be helped. Recent advances in treatment have been made, and today your doctor has several options. So now, more than ever, is an excellent time to consult your doctor. You and your doctor should discuss which treatment option would be best for you.



The prostate is located at the base of the bladder. It surrounds a part of the urethra, the tube that carries urine from the bladder through the penis. As the prostate enlarges, it can squeeze the urethra and cause urinary problems.

If you experience any symptoms, see your doctor and speak frankly about the problem. A simple rectal examination enables the doctor to feel, with a gloved finger, the size and condition of the prostate. This exam, and other tests the doctor may recommend, will also help to rule out the possibility of prostate cancer. Benign prostate enlargement is not cancer and does not turn into cancer.

Talk to your doctor, soon. It's important to you—and your family. And, for a free informative booklet, "What every man should know about his prostate," call 1-800-635-4452.



The little engine that could

(Continued from page 92)

splash-type system used in small four-cycles—which Ryobi claims will be effective even with the engine running inverted. By itself, it would seem unlikely that the dipper system could possibly live up to that assertion. That is, until you learn that both ends of the connecting rod ride on caged roller bearings (rather than conventional insert shells), which get along fine on very small amounts of oil. As a side benefit, the weight, cost, and power

drain of an oil-circulating pump have been eliminated.

The caged roller bearings are fitted into a steel connecting rod that is built up from two separate stampings, rather than the usual casting or forging. The stamped parts are left and right sections; there is no separate bearing cap at the bottom end. This construction technique requires that the crankshaft be pressed together from individual pieces for ease of as-

sembly, and here again Ryobi breaks from tradition by using a stamped counterweight section mated to a simple steel output shaft. Additionally, overall engine weight is kept low by the crankshaft's cantilevered design; the engine is supported in ball bearings only on the flywheel side, ending abruptly at the connecting rod.

The enlightened engineering doesn't end there, either. To eliminate a heavy iron cylinder sleeve, the CleanAir engine is built with a long-lasting, flash-chromed aluminum cylinder bore. The valve train operates from one cam lobe, using an ingenious follower mechanism that simultaneously converts the cam's rotation to the required reciprocating motion and also turns the action 90 degrees to line up with the ball-pivot rocker arms.

In addition to exhaust emissions, Ryobi addressed another form of pollution: noise. While the CleanAir engine's noise level is only a few decibels less than most engines, the biggest difference is its deeper pitch. "The improvement is the quality of the sound," says McLay. "High-pitched sounds and lower-pitched sounds at the same decibel level are two different experiences to the human ear."

Computer-aided-design technology played a major role in this process. "We incorporated a large-volume muffler, but what's more, we used computer-aided design to create noise-canceling baffling," he says. To reduce the noise generated by the gear drive, engineers designed gear profiles that would operate more quietly and then manufactured the gears in a powdered-metal material that provides some advantage in sound damping.

Now engineers are ironing out the last details, including smoothing the engine's vibrations. "We're still fine-tuning that," says McLay. "Four-cycle engines tend to vibrate more than two-cycles because they fire every other stroke."

A 1994 debut

The CleanAir engine will be manufactured almost entirely in Arizona and will first appear in a hand-held grass trimmer at the industry's exposition this summer in Louisville, Ky. Consumers can expect to see that product on store shelves in the first part of 1994. Meanwhile, McLay says Ryobi will consider applying the technology to other outdoor power tool products, such as brush cutters, cultivators, and leaf blowers, as well as licensing the engine to manufacturers of water pumps, mowers, and high-power washers.



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Instruction manuals for all Ruger firearms are available free upon request.

Minivans

(Continued from page 84)

and door openings add up to a vehicle that works physically, including all the loading, unloading, and squirming around that is as much a part of day-to-day driving as taking a hard corner under power.

Our Grand Caravan was equipped with a new handling package that delivered quick steering response and good slalom times on the track. Unfortunately, it was particularly harsh on the highway. By comparison, the performance-equipped Quest stayed relatively quiet and smooth. Normally, the harsh ride associated with handling packages isn't a fair trade-off, particularly for a grocery-carrier like a minivan. The Quest proves it can be done smoothly; the Grand Caravan's handling setup hardly seems worth the aggravation. Overall performance is lively, due to the Grand Caravan's light weight and large-displacement V6 engine.

This year a few worthwhile features have been added to the Chrysler minivan, including vertically adjustable front seat belts and a tilting power seat. The Quest also offers a standard driver-side air bag and still stands out with an optional ingenious built-in child seat. Antilock brakes are available, but, according to Chrysler, rarely ordered. This is unfortunate because an antilock brake system is particularly effective when a vehicle undergoes big load changes. The Quest/Villager's antilock brakes showed to their advantage. ABS is standard on the Villager and optional on the Quest.

Close contenders

Overall, the Ford/Nissan contenders are the closest challenges to the Chrysler classic so far. Given this stage of development, however, it is surprising that the Villager/Quest vans lack certain popular features such as an air bag. But the highway manners and styling of these minivan twins are appealing, particularly if they're not loaded to capacity with people or cargo.

The Volkswagen is an oddly designed chassis with certain interior features that are unique. The camping version will probably emerge as the finest in its class. Its marginal performance is disconcerting, however, and the EuroVan has no offsetting savings in fuel economy.

The Dodge Grand Caravan still represents the optimum package for full, usable seating, reasonable cargo room, and driving comfort. When the available feature list is added in, along with the fact that it is also offered in its original short-wheelbase version, its popularity is unlikely to fade.



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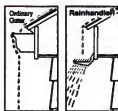
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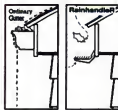
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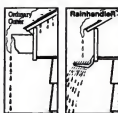
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(Continued from page 63)

an echo that's too high to be an airplane and stops displaying it.

A few miles from a medium-size city lies a walled, heavily guarded compound containing equipment test stands and several small factory buildings. From time to time a siren sounds, and temporary covers are thrown over sensitive equipment. All activity ceases for the few minutes it takes a known spy satellite's imaging path to pass over the base. But no warning is given this morning. Technicians, including two blond Caucasians, are busy preparing a rocket motor for testing on an open stand, and a truck that left a Czech machine-tool factory several days earlier is being unloaded.

All of this detail is faithfully stored on a battery of hard-disk memories by a camera with a 48-inch telephoto lens. Three hours and 15 minutes after its takeoff from Nevada, the spy plane makes a wide turn back toward Northern Europe. The RSO selects the clearest images on his high-resolution screen and transmits them to a satellite with a few keystrokes. In five minutes, hard copies as sharp as an original negative are rolling out of a processing machine 6,000 miles away.

Aurora uses ramjet engines, because no other type can work as efficiently at the speeds the plane travels. In its simplest form, a ramjet is a pinched tube that slows, compresses, and heats the incoming supersonic airstream before adding fuel to it, producing enormous thrust from the hot gas expanding out the exhaust nozzle. However, the compression process also generates tremendous drag. The ramjet designer's challenge is to keep the level of drag from canceling out the slim margin of thrust that propels the aircraft.

One way to make a ramjet engine efficient is to stretch it along the entire length of the vehicle. In a hypersonic ramjet aircraft, the underside of the forward body is a ramp that initially compresses the air before it enters the inlet ducts, and the curved underside of the afterbody guides the expansion of the exhaust gas.

It's a lifting body

The compressed air underneath the body serves a second purpose: It holds the airplane up. At Mach 6, conventional wings would be superfluous appendages creating horrendous drag. Accordingly, the tips of Aurora's delta platform are mainly there to provide stability and control.

The basic problem with ramjets is that they don't work at all unless the aircraft is moving quite fast, and they

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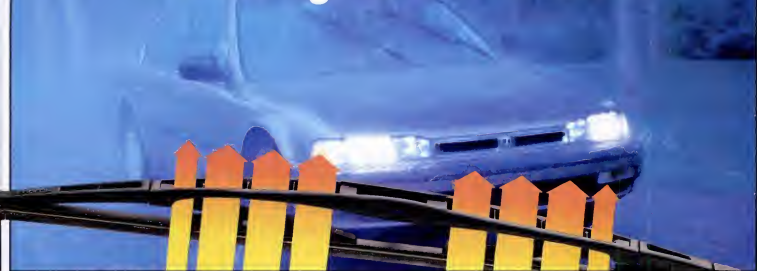
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Secret Mach 6 spy plane

(Continued from page 98)

are not very efficient at speeds less than Mach 2.5. Therefore, Aurora needs some other system to reach this speed.

There are two clues to the way Aurora's designers solved the low-speed propulsion problem. The team for the X-30/National Aerospace Plane (NASP), though tight-lipped about the "accelerator" portion of the NASP engine design, has indicated that it functions as a ducted rocket in parts of its operating cycle. The second clue is that Aurora has been associated with two unusual noises: very-low-frequency pulsing sounds and an extremely loud roar on takeoff.

Rocket-assisted ramjets

The surging or pulsing sound is associated with a class of standstill-to-hypersonic "combined-cycle" propulsion systems invented in the late 1950s and shrouded since then by obscurity rather than security (see The Combined-Cycle Ramjet Engine). Czysz, who studied combined-cycle engines for hypersonic aircraft while at McDonnell Douglas, says that their performance is remarkable. "They go like scalded rabbits," he says.

According to Dr. Fred Billig at the Applied Physics Laboratory of Johns Hopkins University, who experimented with the combined-cycle engine in the 1960s, one of the attractive features of this engine is that it delivers high thrust per unit of frontal area, a drag-reducing characteristic helpful in pushing efficiently past the sound barrier. Most important, the combined-cycle engine can recover energy that most engines throw away. By using cold fuel to cool the airplane's structure and engines, for example, the system converts heat into mechanical energy used to supercharge the ramjet and generate additional thrust.

Super-cold fuel

Even though Aurora is 80 to 90 feet long, which is about 20 feet shorter than the SR-71, it could weigh more—as much as 170,000 pounds when fully loaded. A clear two-thirds of its total mass would be fuel.

Choosing the right fuel was crucial to Aurora's design. Because various sections of the craft will reach cruising-speed temperatures ranging from 1,000°F to more than 1,400°F, its fuel must both provide energy for the engines and extract destructive heat from the airplane's structures. This is done on the SR-71, but at hypersonic speeds even an exotic kerosene, such as the special high-flashpoint JP-7 fuel used by the Blackbird, cannot absorb enough heat. The solution for

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Aurora is a cryogenic fuel—a cold liquefied gas.

The best candidates identified so far are methane and hydrogen. Liquid hydrogen provides more than twice as much energy and absorbs six times more heat per pound than any other fuel. The snag is its low density, which means bigger fuel tanks, a larger airframe, and more drag. While liquid hydrogen is the fuel of choice for a space-launch vehicle that accelerates quickly out of the atmosphere, studies have shown that liquid methane is better for an aircraft cruising at Mach 5 to Mach 7.

Methane (natural gas) is widely available, provides more energy than jet fuels, and can absorb five times as much heat as kerosene. Compared with liquid hydrogen, it is three times denser and easier to handle—inflight refueling has been studied and poses no problems.

Aurora can fly at subsonic speeds because its entire body, which has a great deal of area, is a lifting surface. Also, its sharply swept leading edge—like the Concorde's wing—generates a powerful vortex at nose-high flight angles, which clings to the leading edge and boosts the body's lift. Unencumbered by aerodynamic freeholders such as a conventional fuselage, Aurora's shape is structurally efficient. It packs a lot of fuel and useful equipment into a relatively small volume that saves weight and minimizes friction drag.

The spy plane's airframe may incorporate some stealth technology, but it hardly needs it. Hypersonic aircraft are actually much harder to shoot down than a ballistic missile. Although a hypersonic plane isn't very maneuverable in the traditional sense, its velocity is such that, within tens of seconds, even a gentle turn puts it miles away from a SAM's projected interception point. So why bother with stealth?

Having refueled a second time from a tanker over the North Sea after its Mideast photo session, the black plane heads west at high altitude across the Atlantic Ocean, North America, and beyond the California coast. Decelerating and descending above the Pacific Ocean, the craft drags a sonic boom over the water behind it.

As it turns back toward its Nevada base, part of the inevitable shock wave bends through the upper atmosphere and rumbles across Southern California as Angelinos are getting ready for work. "There goes another one," they say, wondering whether it's a minor earthquake or "that plane we hear about." Time elapsed from takeoff to landing: 6.5 hours. Distance traveled: 15,500 miles.

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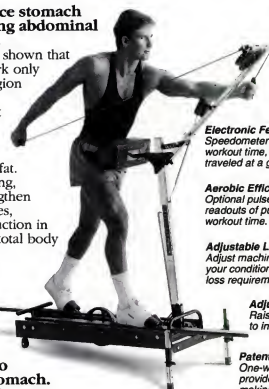
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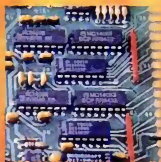
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A house for all reasons

(Continued from page 71)

reduce energy costs or are more environmentally sound include:

- WaterMate electronic metering devices. These small self-contained digital gauges can be installed on water lines, faucets, and sill cocks or irrigation systems. They measure flow volume in gallons, liters, or cubic feet; track water use by the hour or over months; and store and show information on a liquid-crystal display.

- Kohler water-management software. This program for personal computers helps homeowners keep track of water use at every outlet.

- Broan Sensaire motion-detecting, humidity-controlled fans in each bathroom. A light turns on when someone enters the room or shower, and a fan operates automatically when humidity increases.

- A Briggs Turboflush 1.5-gallon toilet. This one-piece pressure-activated unit is installed in the frequently used downstairs powder room.

Kids' "office"

Inside the house, electronics work together to educate, entertain, and provide convenience. A past example of this was the conversion of one room into a home office. But homeowners with young, growing families also take a special interest in their children's education. The learning center addresses that interest by creating an updated, electronic version of a home office for kids.

The focus of this study and work area is Apple Computer's Macintosh Performa 600 CD personal computer. This computer greatly expands the software base and capability of word processors with its built-in CD-ROM drive. Compact discs can store virtually unlimited libraries of information, as well as provide full-motion video, audio, and photography to accompany texts.

With this setup you can rapidly move between software files and CDs and interact with the information to ask or answer questions or view photos and movie clips of the material. A small sample of the educational software and CD titles in the learning center includes Renaissance Masters' Electronic Library of Art, Wordstar's Complete Works for Writing, and the Macintosh edition of the *American Heritage Dictionary with Thesaurus*.

Another educational device in the study area is a Laptop Teacher Super Computer, a coaching tool with a digital voice synthesizer. Voice cartridges convert English to French, Spanish, German, or Italian to quiz kids in grammar, math, history, and geography.

A house for all reasons

(Continued from page 102)

Electronics don't have to be all work and no play, however, even in a learning center. The hottest new video games are also on CDs, and they're just as mind-boggling as the educational discs. The Sega Genesis CD allows players to alter movie plots and interact with actors in lifelike situations.

Not just kid stuff

The latest technology showcased in the New American Home is not just for kids, of course. The house itself was plotted on computer-aided design (CAD) equipment. "A number of suppliers had computer applications for their products—skylights, windows, plaster finish, toilets, etc.—and we were able to plug these into our CAD design," says architect Jan Van Tilberg. "Having the floor plan on computer also made it possible for us to easily modify the layout."

AT&T Videophones lend a futuristic touch in the house, and digital, cordless Escort 900-megahertz phones from Cincinnati Microwave use spread-spectrum technology to enable family members to roam up to a half-mile from home—with no loss of signal.

On the entertainment front, advances in audio and video such as improved-definition TV and Cinema Screen 16-to-9 aspect-ratio TV, both from ProScan, make the home's first and second-floor bedroom suites the kinds of havens that are hard to leave. The family room holds a home theater, interactive CD, and digital sound system (see Sound Effectiveness).

But the practical side to electronics can be just as interesting for would-be home buyers—especially the hands-on types who can't resist "tweaking" their interior environments.

Carrier's new inVironment heating, ventilation, and air-conditioning system, for example, allows for near-infinite variations in room-to-room climate control. A central processor continuously monitors and regulates the system's Comfort Zone network of electronically controlled air ducts and temperature sensors located throughout the house. When signaled by the sensors, powered dampers within the ducts adjust the flow of heated or cooled air to individual rooms.

For each of the home's two zones, this system includes a high-efficiency Synergy 2000 air conditioner, which can idle down to run at half its normal energy use when cooling demand is low. Rated at 12.6 and 12.3 SEER (Seasonal Energy Efficiency Rating, a measure of cooling efficiency), these two units operate well above the new mandated minimum 10-SEER level.

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A house for all reasons

[Continued from page 105]

Likewise, home heating provided by two gas condensing furnaces, rated 93 percent and 91.5 percent efficient, beats the 78 percent mandated efficiency. (The units are sized slightly differently to accommodate the two principal house zones.) In addition, the system includes electronic air-cleaning and humidification.

The home's electrical grid also has been enhanced by adding a number of new products. Unlike the "smart" electronic home systems coming to market, which require expensive proprietary wiring and fixtures, the New American Home relies on standard, off-the-shelf items.

Advanced Control Technologies wall switches are power-line carriers that can be programmed to change lighting functions or act as light and appliance timers. The switches can also transmit and receive control signals to and from different parts of the home.

Even the basic house wiring is not so basic. An Elan HD system from Square D networks the home's high- and low-voltage telephone and coaxial lines. This system enables residents to control the various audio and video equipment scattered from any room in the house; to send audio-video signals from one room to another; to use front-door-mounted minicams to view visitors on any of the home's televisions; and to use the home phones as pagers as well as intercoms.

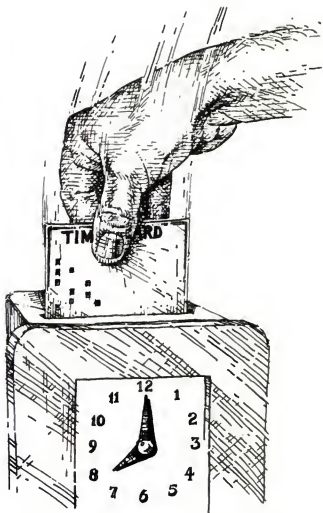
All of these functions are tied together by a Maestro home-control system. Its powerful microprocessor "brain" allows users to consolidate and access the many operations of the home through television-type hand-held remotes, wall-mounted key pads, or any touch-tone telephone. Reprogramming any function in the home—from resetting room temperatures to reconfiguring light-switch operation—is done using preset codes or TV-screen menus. The Maestro system also has its own sensors for door and window security, automatic lighting, and outdoor sprinkler operation.

Tours of the 1993 New American Home are available to industry professionals attending the Home Builders show, and the house will be open to the public for a short time following the convention. After that, it will be sold for an anticipated \$360,000. According to Lewis Homes, its construction cost was higher than that of a typical 3,000-square-foot production home of equal size, a fact reflected in the semi-custom nature of the house. "It's expensive to build as a production home," notes Leah Bryant. But even at that price, she added, the house is still a bargain. **ES**

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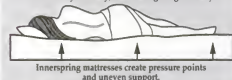
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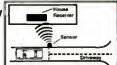
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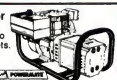
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25 MARCH 1968
YEARS AGO Out of Lockheed by way of the U.S. Army has come a "third-generation" helicopter, born just a quarter-century after this type of flying machine came of age. Its performance is stunning.

Its speed is 100 mph faster than that of any rotary-wing aircraft now in service, Lockheed engineers say. Most of the teeth-jarring vibration associated with helicopters is gone, making the craft a stable gun platform in combat. It also thinks it's an airplane—it can loop and roll. Finally, the new chopper can streak from hovering at zero forward speed to 230 mph in 38 seconds, and decelerate from that to zero hover in 17 seconds.

The performance of the new rotary-wing craft is due almost solely to a change in the blade attachment that has been in use for more than 45 years. The secret is a small, four-arm control gyroscope atop the craft's rotor mast that whirls in concert with the rotor blades.

The Army, always at loggerheads with the Air Force over which service will own what combat aircraft, is delighted with the Cheyenne. As a gyro-stabilized gun platform with computerized fire control and laser-beam range-finding, it is designed to escort troop-transport choppers into battle. But the helicopter also is capa-



The Army plans to buy hundreds of the new 250-mph Lockheed Cheyenne helicopters.

ble of search-and-destroy missions, flying low and slow, or high and fast, with a versatility beyond that of fixed-wing jets.

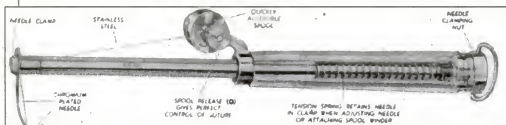
50 MARCH 1943
YEARS AGO An adaptation of the sewing machine's "uninterrupted thread supply" to surgical suturing has resulted in a new stitcher. This mechanical device cuts precious minutes from operating time and eliminates the danger of

spreading infection. The secret of the instrument's speed is that the needle can shuttle back and forth without stopping for fresh thread with every stitch. When the tip of the device is inserted, the needle is driven into the skin only far enough to allow the surgeon to catch the loop of the suture, so

that no part of the thread is needlessly contaminated. The surgeon then knots the thread, snips it with the sharp lance point of the needle, and, with a slight pressure of his thumb, releases sterile thread for the next stitch.

A novel feature of the suturing unit's metal container, which has been designed for military use, is a bayonet that can be extended from the side of the case and driven into the ground. The surgical stitcher was developed by the Singer Sewing Machine Company.

A mechanical stitcher speeds surgical sutures.



100 MARCH 1893
YEARS AGO Rainfall is the source of all underground water, and with the exception of certain deep-seated artesian wells, the source is always the rain that falls in the immediate vicinity.

Part of the rainfall is quickly drained away by surface channels, a part is evaporated, and a third is imbibed by the rocks and soil. The distribution of the rainfall in the above manner varies with the climate and geologic conditions, but so far as underground waters are concerned, it is necessary to consider only the water that sinks into the ground.

That portion of the earth visible to human inspection is more or less sat-

urated with water. In times of drought and in arid regions this is not always evident at the immediate surface, where evaporation is taking place. But, a post hole, a blast in a quarry, or a newly dug well reveals the dampness of the rock material. This moisture is sometimes invisible to the eye, but in general its quantity varies in proportion to the compactness or porosity of the rocks, the number of joints, fissures, or other crevices, and the topographic situa-

tion that controls the drainage in the area.

All rocks imbibe moisture in proportions varying with their physical structure. Rocks that have imbibed all the moisture they can contain are in a condition of saturation, and all water in excess of this amount will pass off by gravity or evaporation. The excess above the saturation point is available as the source of springs, but the supply of wells is from the saturated ground.



The drawing shows a favorable geologic structure for an artesian well (far right).

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